

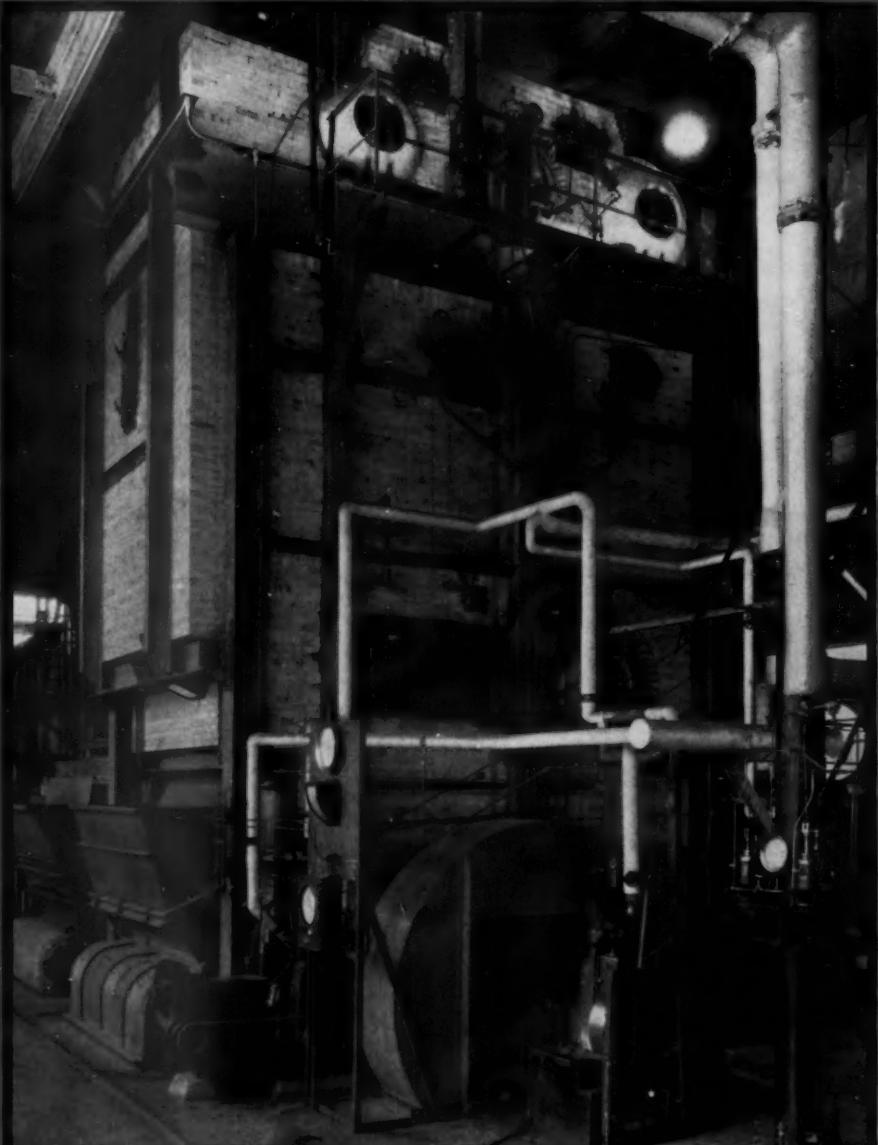
# COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 6, No. 5

NOVEMBER, 1934

25c a copy



New boiler unit at Colgate-Palmolive-Peet plant, Jeffersonville, Ind.

## Regulation of Steam Temperature by Controlled Gas Flow—Part I

Slag Bottom Furnace Experiences at Hell Gate Station

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# COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME SIX

NUMBER FIVE

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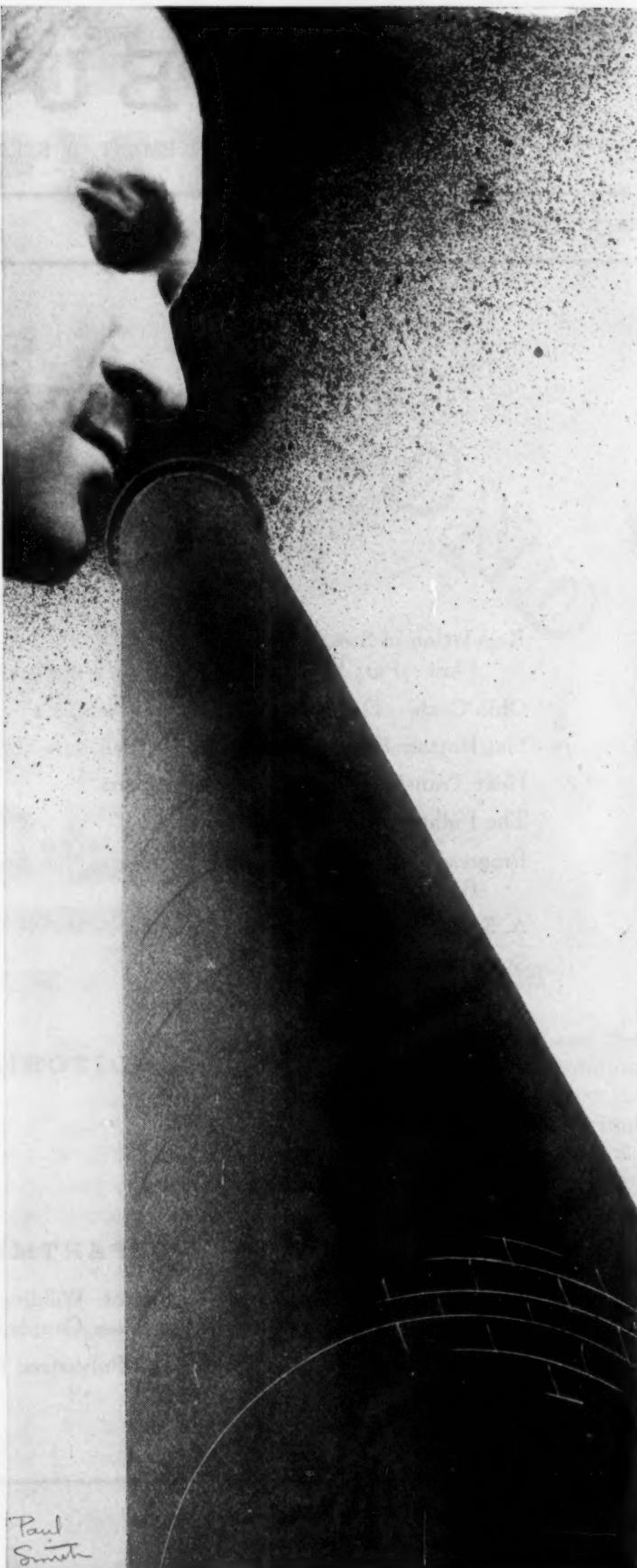
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THE POWER CAPITOL OF THE WORLD

1934 NATIONAL POWER SHOW

# *and the POWER ENGINEER'S future*

## The Power Show

\* **N**EXT week is Power Week in New York.

The Power Show will be open.

There will be thousands of owners, managers and engineers of power plants come to see the latest developments in appliances, apparatus, methods and materials for their use.

And at the meeting of the American Society of Mechanical Engineers, simultaneously in progress, papers will be presented and discussed by the leading exponents of power-plant practice.

Did you ever think how many things there are of which you got your first knowledge at a Power Show or Mechanical Exposition, or some kind of a Fair?

In what clumsy and ineffectual ways we would be doing things if it were not for the inventions and developments that are there on exhibition.

But just as in one's own day's work one might as well not have a thing as to

have it and not know it, so the craft collectively suffers by lack of universal knowledge and appreciation of the tools and materials at its command.

These expositions offer the best of opportunities for the producer and promoter of such appliances and supplies to meet their potential customers and users.

And for the user to meet the producer of the machines that he runs and the materials that he works with and to discuss with him their performances and maintenance.

And they afford opportunities for the meeting and reunion of managers, engineers, and the exchange of experiences, plans and views.

I have attended many of them and never one without seeing something new or somebody with something interesting and valuable to tell.

Big rewards go to men who do big things, and unprecedented opportunity is wide open to the real power engineer. Industry knows that power cost must and can come down. Only those who can produce, transmit and use power by the most economical modern methods will survive and advance. To insure your own future, come to this year's National Power Show and see for yourself how your power costs can be cut down by means of the new products on demonstration by leading manufacturers. Exhibits, many of them in operation, will be in charge of engineering specialists, eager and able to answer your questions and to help solve your problems.

Come to examine, compare, inquire and discuss. It is your immediate opportunity to keep pace with progress and gain its rewards.

\* Printed one week before the opening of a previous Power Show.

## 11th NATIONAL EXPOSITION OF POWER AND MECHANICAL ENGINEERING

Grand Central Palace, New York

Dec. 3-8, 1934

Management, International Exposition Co.



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## EDITORIAL

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### Why Not Get at the Facts?

An important reaction to the coal industry's persistent attacks on the TVA is a proposal from Arthur E. Morgan, Chairman of the Tennessee Valley Authority, that the campaign of unsupported denunciation cease and that a body of competent, disinterested investigators be selected to make an inquiry comparing the cost of generating electricity at the Wilson, Norris and Wheeler Dams with that of steam plants.

Mr. Morgan's proposal, made at a meeting of the research division of the National Coal Association, is in line with his broad gage thinking and often-expressed views.

The suggestion is commendable and the results of such an investigation should prove valuable providing those selected to do the work are not only unbiased but also possess the necessary background of experience. The problem is far from simple, involving not only a legacy of war-time expenditures but also expenditures made to relieve the present unemployment situation, which would involve a careful determination of fixed charges and an analysis of seasonal stream flow, involving certain steam plant reserves. In this connection it is pertinent to recall that, despite an increase in hydro capacity, the central station energy generated throughout the country by water power for the twelve months ending August 31, 1934, was 36.5 per cent of the total generated as compared with 40.9 per cent for the corresponding period of 1933. This was due to the drought period during the summer, which condition may be expected to recur.

If it is decided to go ahead with Mr. Morgan's proposal, and if the personnel of certain existing Governmental agencies be taken as a criterion, it would be highly desirable that the investigators be selected by one or a group of the national engineering societies, as this would inspire confidence in the findings.

Furthermore, a determination of relative power costs from steam and hydro plants, as pertains to the Tennessee Valley development might prove enlightening to the Government in connection with some of the other hydro projects upon which it has embarked. While the results would not be strictly comparable to these other projects, they would serve as a far better guide than the pressure of local political opinion.

The Government is now engaged in making a national power survey with particular reference to rates charged for electricity throughout the country. While the data collected will undoubtedly be susceptible of analysis that could throw much light on relative steam and power costs, the results are not likely to be of much value to the specific issue between the coal industry and the TVA. Moreover, with the Government pledged to a definite program of hydro development, the findings of such a Governmental agency would carry less weight than those of an independently selected body, made up of individuals experienced in power matters.

### For Greater Uniformity

When Herbert Hoover was Secretary of Commerce an intensive drive was undertaken by that department toward achieving greater standardization of manufactured products. Much was accomplished by the Division of Simplified Practice, with the cooperation of trade associations, in reducing the multiplicity of designs, shapes, sizes, etc., which resulted in large manufacturing savings, a reduction in stocks carried, and in greater convenience to the customer. The manufacturer was thereby able to devote more time and money to research and development in improving the quality of his product.

Little attempt has been made to apply the idea to the power plant field, although when one considers the great variety of designs, sizes, pressures, temperatures, heat cycles, methods of firing and combinations of equipment found in the power plants throughout the country, with hardly any two plants alike, the possibility of effecting some degree of uniformity appears attractive.

If this could be brought about, it would benefit both manufacturer and user, but unlike manufactured products sold in large quantities, the power plant is essentially a tailored job, governed by many local conditions of which load, available fuels and often process steam requirements, are important factors. About the only place in which standardization of steam generating practice is found to some extent is in the oil fields where conditions do not vary greatly.

Furthermore, it can be argued with much substantiation that any attempt at standardization would have impeded the remarkable progress that has been made in power plant practice over the last ten or fifteen years. This is especially true of the larger installations and of equipment designs and operating practice which must ever remain to some extent in a state of evolution. However, as the "law of diminishing returns" becomes more and more applicable to steam plant cycles and practices, the urge toward attainment of still better economy will likely be subordinated to considerations of investment costs and operating simplicity.

Despite the many apparently insurmountable obstacles, it may be possible, by the cooperation of manufacturers and designers, and through education of users, to reduce the number of equipment sizes, to agree on certain pressures and temperatures to meet given conditions, and to gain acceptance of certain types of firing for fuels of definite characteristics. The idea might well be applied to those industrial plants where conditions are essentially similar and where accepted designs have proved both efficient and reliable, leaving future pioneering to those stations that are best fitted to carry on such work.

In the electrical field, definite voltages and frequencies have long been accepted as standard as well as certain types of construction. Perhaps something may be accomplished in the steam field.

# Regulation of Steam Temperature by Controlled Gas Flow—Part I

## THE COMPENSATING SUPERHEATER

During the past fifteen years there has been a growing appreciation of the necessity for a superheater design which will give a reasonably flat temperature curve over a wide load range. The present trend toward higher steam temperatures has created an even more vital interest in the subject.

This article is divided into two parts. The first, by Mr. Rieder, deals with the history and development of superheaters, with special reference to the designs used in the power plants of The Detroit Edison Company. A description is also given of a new type known as the "compensating superheater," the first commercial installation of which was made in the Trenton Channel Power House. The operation of this installation is discussed and its performance compared with other types of superheaters. A short description of a somewhat similar design to be used in the Connors Creek Power House is also included. The second part of the article, written by C. W. Gordon, deals with the history and development of steam temperature regulation and with the theory and design of the compensating superheater. This will appear in the December issue.

THE first practical application of superheated steam was made as early as 1828 and from that time its use gradually increased until 1870. During this early period reciprocating steam engines were used. With this type of prime mover, the oil utilized to lubricate the cylinder comes into direct contact with surfaces at or near steam temperature and, as a consequence, the maximum total steam temperature is limited by the properties of the lubricant used. When the limit had been reached for the oils available at that time, the interest in high-temperature steam materially decreased. However, beginning about 1884, the introduction of the steam turbine as a prime mover for power generation, together with its application in the industrial field, was responsible for a revival of the use of superheated steam. The fact that turbine economy is so materially affected by steam temperature stimulated the development of superheaters so that higher steam temperatures were made available.

By E. V. RIEDER  
Acting Technical Engineer  
Trenton Channel Power House  
The Detroit Edison Company

After a few unsuccessful attempts to install superheaters in or near the furnace, the location at the boiler outlet became standard for the early designs. As the knowledge of the designer increased, particularly as to the effect of steam velocity on metal temperature, superheaters were moved step by step closer and closer to the furnace.

The development of boilers and superheaters at The Detroit Edison Company is reviewed by Figs. 1 to 5 inclusive and the accompanying description of these representative installations.

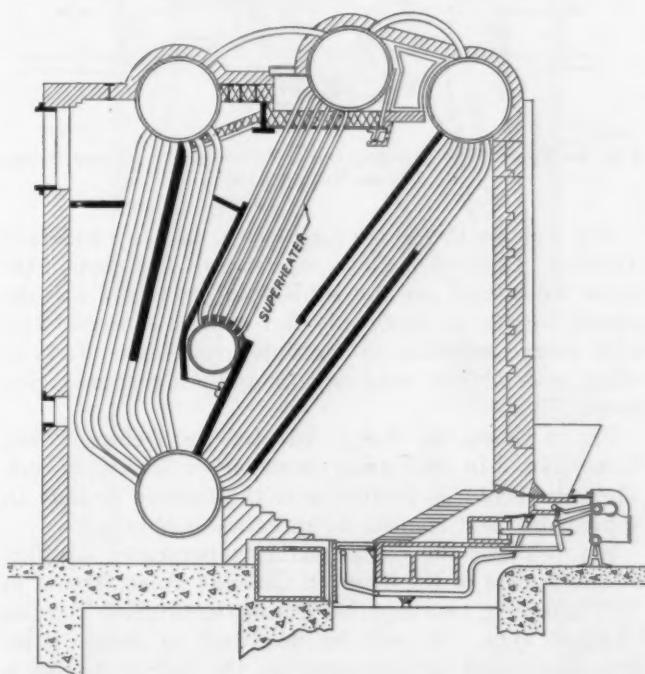


Fig. 1—First design adopted for the Delray Power House No. 1 in 1904

Fig. 1 shows the first design adopted for Delray Power House No. 1 in 1904.

Fig. 2 shows the type "W" Stirling boiler developed for Delray Power House No. 2 and installed in 1909. Similar designs were followed later in Connors Creek (1914) Marysville (1922) and Trenton Channel (1924) Power Houses.

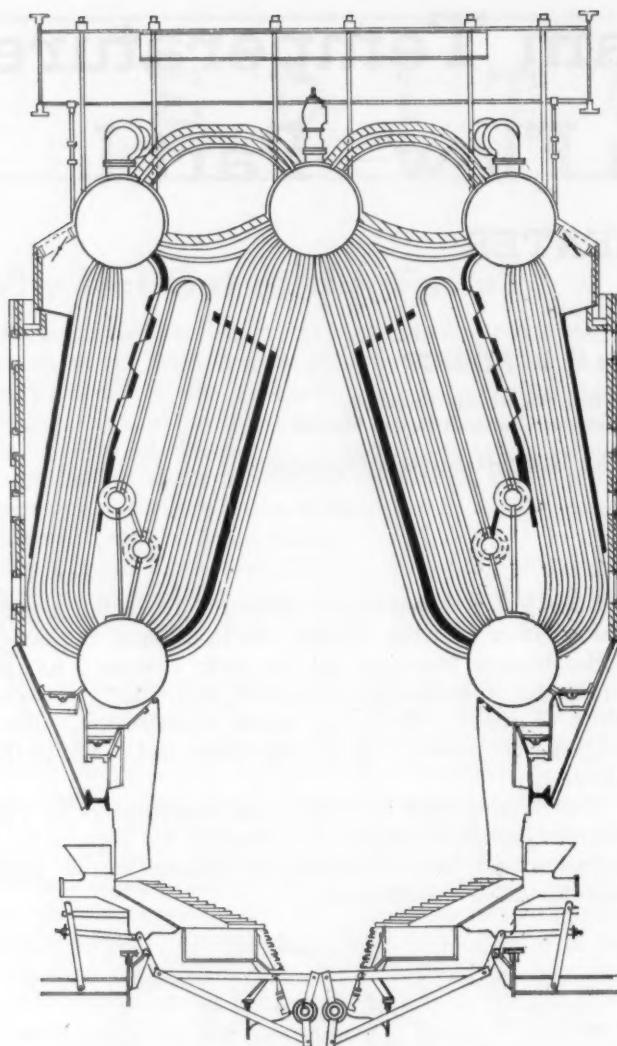


Fig. 2—Type "W" Stirling boiler installed in Delray Power House No. 2 in 1909

Fig. 3 shows the design used for the last two boilers at Trenton Channel. This superheater employed the latest knowledge on the subject in 1928 and was designed to give a reasonably flat superheat curve with high steam velocities in multiple loop units. It is in effect a combined semi-radiant and convection superheater.

Fig. 4 shows the design adopted for Delray Power House No. 3 in 1929 using single-ended Stirling boilers. The superheater is located near the furnace so that an appreciable heat transfer by radiation is obtained.

Fig. 5 shows the compensating superheater installed in two boilers of the Trenton Channel Power House in 1932 replacing two superheaters of the original Trenton Channel type. It will be described in detail later. It is mentioned here to complete the picture as this is the latest operating installation of The Detroit Edison Company.

#### Performance Curves

The temperature-steam flow curves of Fig. 6 show the development for the designs shown in Figs. 1 to 5. The curves are from actual tests and are interesting in that they show the development in capacity and in final steam temperature as well as the improvement in the shape of the curve over the load range.

#### Experimental Work on Convection Superheaters

The desire to improve the characteristics of the older pure convection superheaters led to a number of experiments with various baffle and damper arrangements. The locations of these baffles and dampers, with respect to the superheaters in the Trenton Channel Power House, are shown in Fig. 7. The problem in these boilers was to direct the gases to the superheater, and in addition, to prevent the concentration of gas flow along the metallic baffle at low ratings.

Fig. 7a shows four different baffle arrangements which were tested individually. No. 1 baffle resulted in a 10 to 15 deg increase in steam temperature at the lower ratings. However, the steam temperature at high ratings exceeded the allowable limit. Similar results were experienced with baffles Nos. 2 and 3. No. 4 baffle was found to be the most successful of this type, since, at high ratings, the maximum allowable steam temperature was not exceeded. However, 5 to 10 deg in steam temperature were gained at the lower ratings. It appeared that, in order to obtain a high temperature at low ratings and not to exceed the limit at high ratings, it would be necessary to install a baffle that could be adjusted to suit the different steaming rates of the boiler.

Fig. 7b shows the next type of baffling tried. The hinged baffle placed in position 5 did not accomplish the desired results.

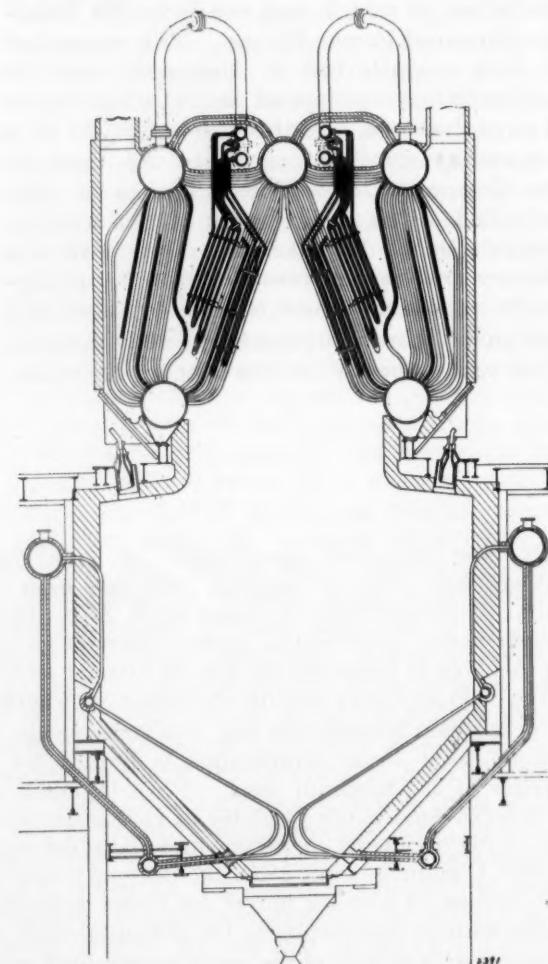


Fig. 3—Design used for last two boilers at Trenton Channel Power House in which the combined semi-radiant and convection superheater was developed to give a reasonably flat superheat curve with high steam velocities in multiple loop units

### Trenton Channel Installation

The first commercial installation of the compensating superheater was made in April, 1932 in one of the type "W" Stirling boilers at the Trenton Channel Power House. This superheater consists of three sections which are in effect three separate superheaters, arranged and interconnected as shown in Fig. 5. The two semi-radiant sections are located in the front bank of tubes on either side of the furnace apex. The convection ele-

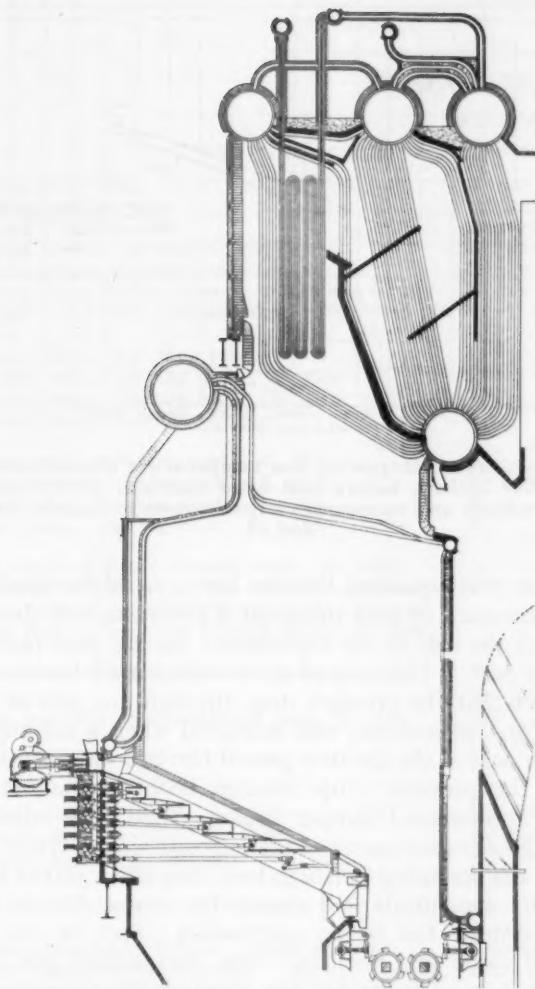


Fig. 4—Design of single-ended Stirling boilers in Delray Power House No. 3, 1929, in which the superheater is located near the furnace so that appreciable heat transfer by radiation is obtained

Fig. 7c shows the next step which was to experiment with a baffle in location 6. A slight improvement was noted, and in an attempt to magnify this improvement, a hinged baffle was placed in position 6A. The results of this arrangement were not as satisfactory as No. 6 baffle alone.

Fig. 7d shows another attempt to improve No. 6 arrangement by the use of baffle No. 6B, thereby concentrating the gases on the superheater elements. Baffle No. 5 was not in use during this test. Baffle No. 6B showed no appreciable improvement, and it was thought that by adding baffle 6C less gas would pass through the open space between the loops. This caused the steam temperature limit at high ratings again to be exceeded so baffles 6B and 6C were removed and a combination of baffles 5 and 6 was tried. The results of this combination were no more satisfactory than baffle No. 4 alone. Consequently, in view of its simplicity and effectiveness, all of the boilers with this type superheater were equipped with No. 4 baffle. A series of curves comparing the temperature characteristics of these boilers, before and after baffling, with those of the semi-radiant and convection superheaters in Boilers No. 13 and 14 (the last boilers to be installed), are shown in Fig. 8. It can be seen that although improvements were effected, a straight line characteristic was not by any means obtained.

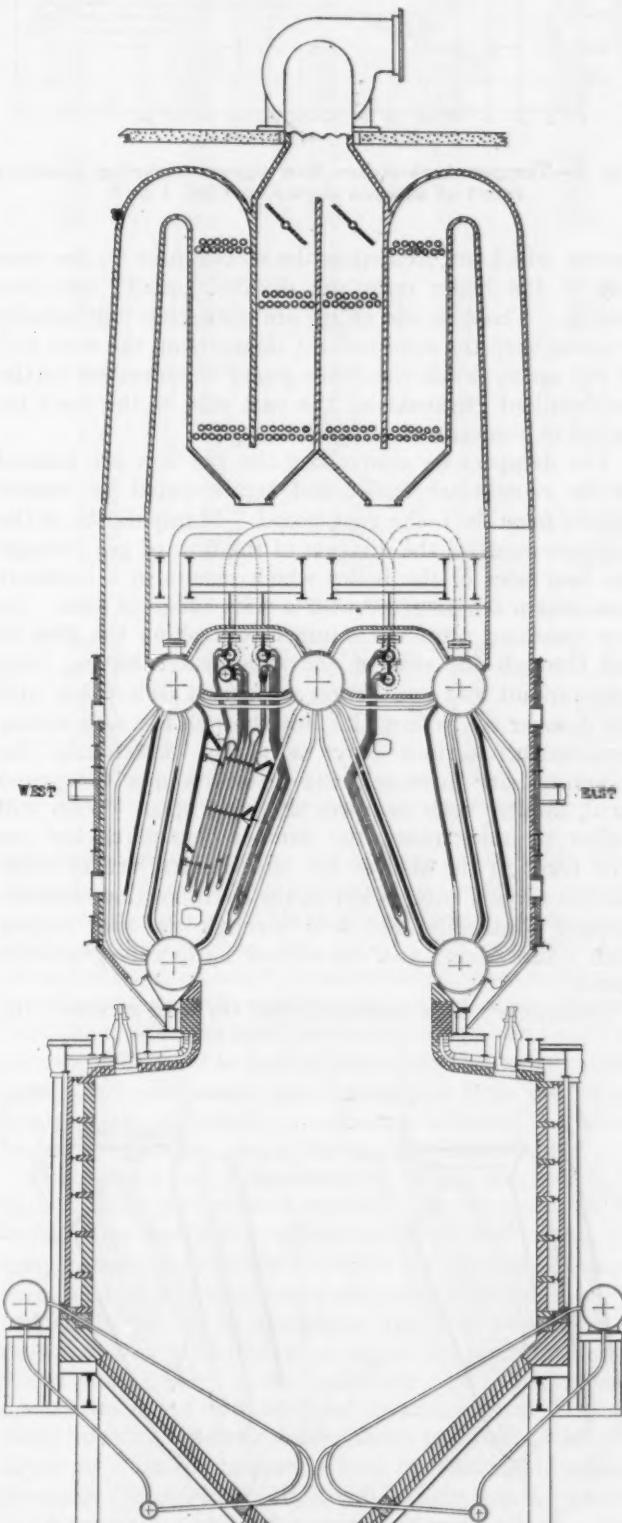


Fig. 5—Compensating superheater installed in two boilers at Trenton Channel Power House in 1932

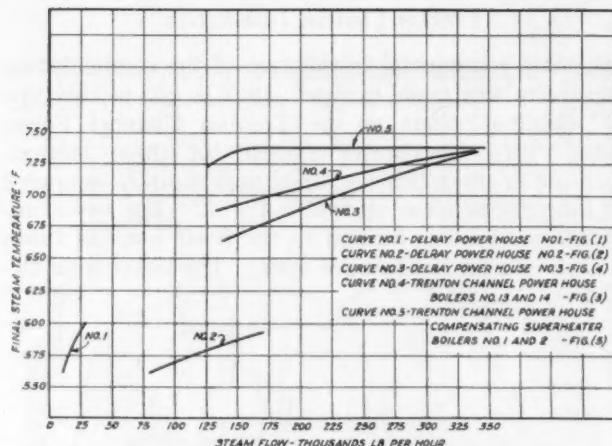


Fig. 6—Temperature-steam flow curves covering development of designs shown in Figs. 1 to 5

ments, which are located in the second pass on the west side of the boiler only, are divided equally into two groups. Those in one group are connected individually in series with the semi-radiant elements on the west side of the apex; while the other group is connected to the semi-radiant elements on the east side of the apex by means of headers and a connecting pipe.

The dampers for controlling the gas flow are located at the economizer outlet and are actuated by remote control from the boiler gage board. Manipulation of the dampers controls the division of the flow of gas through the two sides of the boiler which results in a constant final steam temperature over a wide range of load. At low steaming rates the damper controlling the flow of gas through the side of the superheater having both semi-radiant and convection surface is wide open, and the damper controlling the flow through the side having semi-radiant surface only, is partly closed. As the steaming rate increases, the latter damper is opened until, finally, both dampers are wide open. With still higher steaming rates, the damper controlling the gas flow through the side of the superheater having semi-radiant surface only, is left in the open position, and the damper controlling the flow through the side having both semi-radiant and convection surface is gradually closed.

Preliminary tests indicated that the load at which the

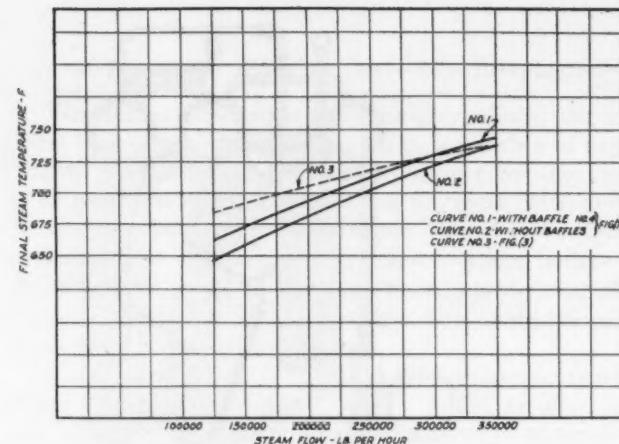


Fig. 8—Curves comparing the temperature characteristics of earlier boilers, before and after baffling, with those of semi-radiant and convection superheaters in boilers No. 13 and 14

gas flow was equalized was too low. At higher loads it was necessary to pass too great a percentage of the gas through the side of the superheater having semi-radiant surface only. This caused an excessive draft loss due to the fact that the pressure drop through one side of the boiler and economizer was increased when a disproportionate part of the gas flow passed through one side only. Since the pressure drop through both sides must be equal, an increased damper resistance had to be imposed in the economizer outlet of the opposite side. When the boiler was operating at a high load, this effect was of considerable magnitude and caused the motor driving the induced-draft fan to be overloaded. Part of the increased draft loss resulting from unequalized gas flow was due to an increased loss through the economizer. It would have been advantageous to be able to unite the gas streams before they enter the economizer and to locate the control dampers at the boiler outlet rather than at the economizer outlet. Such a change was not possible however in the existing arrangement except at unwarranted expense. Since, all other factors being constant, the temperature of the steam leaving a superheater is decreased when the surface exposed to the gas is decreased, it was possible to raise the point of equally divided gas flow to maximum load by removing tubes from both sides of the semi-radiant superheater.

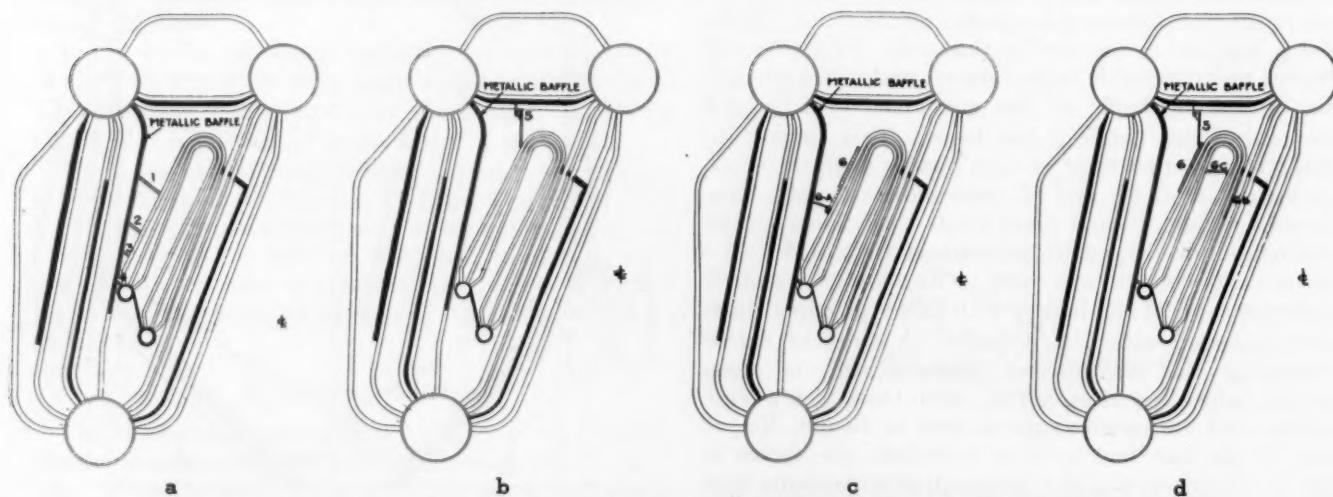


Fig. 7—Experimental baffle and damper arrangements with respect to the superheaters in the Trenton Channel Power House

TABLE I  
SUMMARY OF TESTS ON COMPENSATING SUPERHEATER

Trenton Channel Power House

Steam flow total	lb per hr	124,300	174,400	239,500	299,900	344,700
Steam flow, E. side	lb per hr	63,900	88,700	121,200	150,300	173,200
Steam flow, W. side	lb per hr	60,400	85,700	118,300	149,600	171,500
Steam press., saturated drum	lb per sq in. gage	401	404	412	413	422
Steam press. at main steam header	lb per sq in. gage	396	395	398	394	399
Press. drop boiler drum to main steam header	lb per sq in. gage	5	9	14	19	23
Final steam temp., superheater outlet	F	721	736	737	736	737
Water temp., entering econ.	F	217	227	224	219	234
Water temp., leaving econ., E. side	F	254	270	289	327	363
Water temp., leaving econ., W. side	F	354	356	337	330	329
Water temp., entering boiler	F	305	313	311	326	341
Gas temp., entering econ., E. side	F	430	464	536	630	705
Gas temp., entering econ., W. side	F	539	575	592	613	633
Gas temp., leaving econ., E. side	F	237	257	278	318	365
Gas temp., leaving econ., W. side	F	291	312	310	317	338
Per cent of water through econ., E. side		52.5	52.1	50.5	50.0	43.5
Per cent of water through econ., W. side		47.5	47.9	49.5	50.0	56.5
Per cent of gas flow through econ., E. side		28.0	32.0	39.3	48.0	52.7
Per cent of gas flow through econ., W. side		72.0	68.0	60.7	52.0	47.3
Gas analysis at superheater pass, E. side	CO <sub>2</sub> content, %	13.1	14.6	15.9	15.2	15.6
	O <sub>2</sub> content, %	6.0	4.3	2.8	3.6	3.1
Gas analysis at superheater pass, W. side	CO <sub>2</sub> content, %	12.7	13.9	15.4	14.5	15.8
	O <sub>2</sub> content, %	6.5	5.1	3.3	4.3	3.1
Draft, apex of boiler furnace		0.00	0.03	0.06	0.17	0.20
Draft, boiler outlet, E. side	in. H <sub>2</sub> O	0.20	0.30	0.80	2.10	4.20
Draft, boiler outlet, W. side	in. H <sub>2</sub> O	1.10	1.75	2.40	3.18	3.40
Draft, economizer outlet	in. H <sub>2</sub> O	2.10	3.80	4.60	5.95	6.60
Input to induced draft fan motor	amp	100	265	340	677	1,100
Heat absorbed by boiler, supptr and econ.	% of calorific value of fuel as fired	89.42	89.14	88.71	87.97	87.39
Heat loss, moisture in coal		0.22	0.22	0.22	0.23	0.23
Heat loss, moisture formed in burning H		3.46	3.47	3.52	3.63	3.98
Heat loss in dry chimney gases		5.65	5.91	5.54	6.46	5.98
Heat loss, moisture in air		0.05	0.05	0.05	0.06	0.06
Heat loss, unconsumed carbon in ash		0.62	0.63	1.37	1.05	0.63
Radiation and unaccounted for losses		0.58	0.58	0.59	0.60	0.60

Following these changes a series of tests was conducted to secure data on the operating characteristics of the modified installation. During these tests special attention was given to items likely to be affected by unequalized gas flow. Table I shows the tabulated results. Since it is difficult to measure the coal burned in these boilers with any degree of accuracy, the heat absorbed by the boiler, superheater and economizer, and the six

heat losses enumerated at the bottom of the table were computed. The total heat flowing to the boiler was assumed to be the sum of these items, and the percentages given are based upon this total. The radiation loss instead of being included in unaccounted losses and found by difference, as is the usual procedure, was approximated from the results of a previous test in which this item had been measured. The heat absorbed by the boiler, superheater and economizer was determined from the steam flow and the difference in enthalpy between the boiler feedwater and the steam leaving the superheater.

The superheater performance is shown graphically in Fig. 9. The anticipated results were obtained at all loads. Due to the fear of the corrosive effect of low gas temperatures in the economizer on the east side at minimum load, it was considered undesirable for loads below 160,000 lb per hr to unequalize the flow more than is shown in the upper curve of steam temperature versus steam flow. Short tests indicated that with greater unequalization of flow, the final steam temperature curve could be extended horizontally down to a load of 125,000 lb per hr. As the minimum load for this installation is normally 160,000 lb per hr, it will be seen that a constant temperature is obtained over the operating load range. As a matter of interest, the dotted curve is drawn to show the performance with equal gas flow through the two

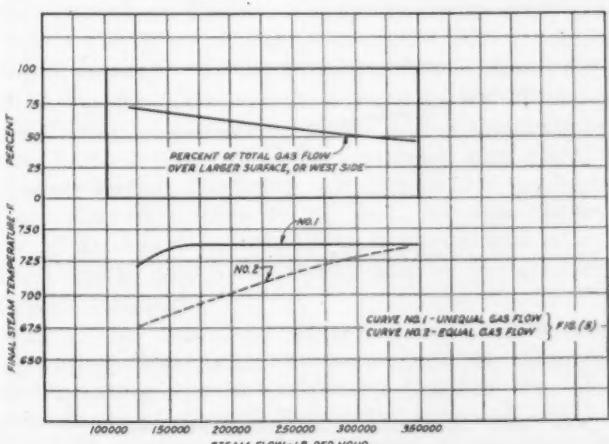


Fig. 9—Performance curves of compensating superheater at Trenton Channel Power House

sides of the boiler. This curve is practically coincident with those obtained on boilers Nos. 13 and 14, and thus illustrates the improvement of the compensating super-

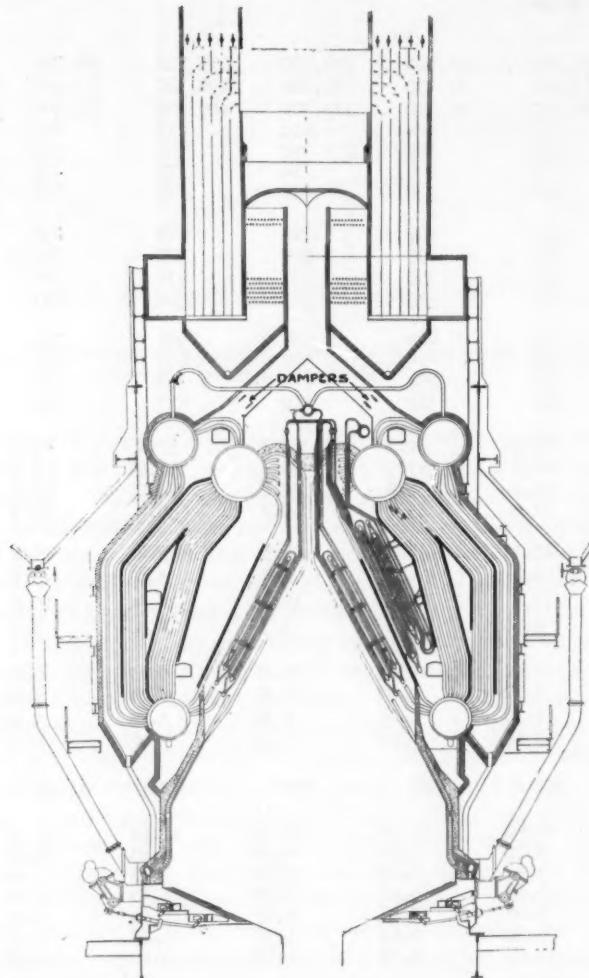


Fig. 10—Design of steam generating unit at Connors Creek Power House which includes a compensating superheater

heater over the most advanced standard designs of semi-radiant and convection type superheaters in this power house.

Comparison of the efficiency curve obtained for this boiler with the curve obtained before installation of the compensating superheater indicated a decrease in efficiency at the lower ratings. The difference, however, is slight, being 0.3 per cent at a steam rate of 175,000 lb per hr. This difference is within the range of experimental error.

The power required by the induced-draft fan was greater than for similar boilers with standard superheaters at the lower ratings due to the large percentage of gas passing through the side of the boiler having the greater frictional resistance (the side having both semi-radiant and convection surface), and to the increased damper resistance on the opposite side producing this unequal flow. In any case it was not excessive and no increase in fan size was required since the flow was practically equalized at maximum load.

No disturbance in the boiler drum water levels occurred at any load due to unequalization of gas flow.

As a result of the success of this installation, the new boilers for the Connors Creek Power House are to be equipped with compensating superheaters.

### Connors Creek Installation

The Connors Creek units are designed to operate at 645 lb per sq in. gage pressure at the superheater outlet and to deliver steam at a constant final temperature of 850 F at all steaming rates within the operating range. Fig. 10 shows the design of the complete steam generating unit which includes a compensating superheater similar to the Trenton Channel installation.

The dampers for adjusting the gas flow through the two sides of the boiler are located at the boiler outlets. In this position unequal gas flow conditions are limited to the boiler only as the gases from the two sides combine before entering the economizer.

In Table II the estimated performance for this installation is given. The predicted curves of superheater performance and gas flow are shown in Fig. 11.

Since this is a new installation, reasonably free of restrictions in design, exceptionally good performance is anticipated.

### Operating Conclusions

In conclusion, the advantages resulting from the operation of boilers equipped with compensating superheaters will be briefly summarized:

1. A final steam temperature versus boiler output curve in the form of a horizontal straight line can be obtained throughout the operating load range.

2. In the case of boilers equipped with standard superheaters, the steam temperature at a given load increases as the evaporating surfaces become dirty, necessitating flue blowing and hand lancing of the evaporating surfaces. With the compensating superheater installation, this variation can be corrected by a different adjustment of the dampers.

3. With the standard type of superheaters, it is often found that the increased steam temperature obtained by operating the boilers with low CO<sub>2</sub> at low ratings increases the turbine efficiency enough to more than compensate for the decreased boiler efficiency, thereby giving a small net gain. With the compensating superheater, this gain resulting from higher steam temperature is obtained without sacrificing boiler efficiency.

4. The only extra operation necessary in firing these boilers is the change in the relative adjustments of the two dampers as the load is increased or decreased.

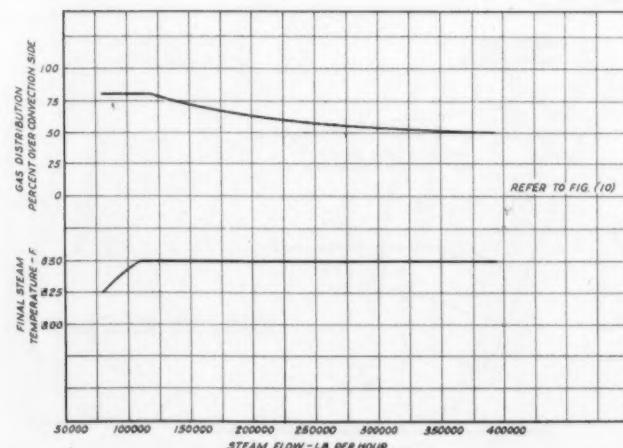


Fig. 11—Predicted curves of superheater performance and gas flow at Connors Creek Power House

TABLE II							
PREDICTED RESULTS COMPENSATING SUPERHEATER							
Connors Creek Power House							
Steam flow	lb per hr	59,400	163,000	245,000	329,900	375,000	388,000
Fuel Consumption	lb per hr	6,400	16,000	24,000	32,500	37,500	39,000
Steam pressure, superheater outlet	lb per sq in. gage	645	645	645	645	645	645
Final steam temperature, superheater outlet	F	800	850	850	850	850	850
Gas analysis at superheater pass:							
Carbon Dioxide, CO <sub>2</sub>	%	15.8	16.0	16.1	16.15	16.1	16.1
Carbon Monoxide, CO	%	0.0	0.0	0.0	0.1	0.2	0.3
Total gas available	lb per hr	74,100	194,800	290,000	388,000	444,000	459,000
Distribution of gas:							
Radiant side	%	20	31	40	47	50	51
Radiant and convection side	%	80	69	60	53	50	49
Draft loss through superheater only							
Radiant side	in. H <sub>2</sub> O	-	-	0.025	0.060	0.090	0.100
Radiant and convection side	in. H <sub>2</sub> O	0.06	0.30	0.50	0.70	0.80	0.83

After the boiler and superheater have been tested and in operation for a short time, the necessary damper positions for any given load are known and adjustments can be made very rapidly.

5. The regulating dampers are located in a relatively cool zone and give no operating trouble.

6. In a power plant equipped with compensating superheaters, it would be possible to hold the steam tem-

perature at the turbine throttles relatively constant. Since there would be less variation in temperature with such an installation, a higher average value would be obtained. This would result in a two-fold advantage: first, a saving in steam consumption; second, a reduction in moisture content, and therefore in the erosive effect in the last turbine stages.

Bert Houghton, well known in central station operating circles has retired as Operating Superintendent of the Brooklyn Edison Company, after more than twenty-one years in that capacity. Mr. Houghton, before coming with the Brooklyn Edison Company in 1912 was for fifteen years engaged in the design and installation of generating plants and substations with the Boston Electric Light Company and later the Boston Edison Company. Following his graduation from Cornell University in 1892, he was employed by E. D. Leavitt, consulting engineer, and later by the General Electric Company and by the Lockwood Greene Company.

E. C. M. Stahl, for several years past Assistant Operating Superintendent succeeded Mr. Houghton as Operating Superintendent on October 10. He is a graduate of Cornell University, class of 1913 and has held successively the positions of electrical field engineer, assistant superintendent of Hudson Avenue Station and engineer of tests with the Brooklyn Edison Company.

**E. H. Tenney**, Chief Engineer of Power Plants of the Union Electric Light & Power Company, St. Louis, has been elected President of the St. Louis Engineers Club.

**A. C. Fieldner**, Chief Engineer, Experiment Stations Division, of the U. S. Bureau of Mines has been elected Vice president of the American Society for Testing Materials.

**Henry M. Chase**, since 1891 a member of the engineering department of Worthington Pump and Machinery Corporation has recently retired from that organization. During this long service he was successively designer, field and shop test engineer, research engineer, chief draftsman, chief engineer and consulting engineer. He was long actively identified with the development of compound pumping engines, power pumps and direct-acting steam pumps.

# Ohio Coals— Their Classification and Analyses

By P. B. PLACE Combustion Engineering Company, Inc.

The Middle Kittanning (Ohio No. 6), the Pittsburgh (Ohio No. 8) and the Upper Freeport (Ohio No. 7) are the three important coal seams in Ohio. Most of the coal produced comes from Belmont, Jefferson, Harrison, Athens and Guernsey counties representing the Pittsburgh, Hocking Valley and Cambridge districts. To assist in the identification of, and in the setting up of an analysis for, an Ohio coal, a brief description of the coal measures is given and basic moisture and ash-free analyses of the principal seams have been prepared. An introductory article by the author, in the October issue discussed broadly, "Analyses of Coals of the United States." Subsequent articles will discuss, in detail, coals of other producing states.

THE coal bearing region of Ohio is in the southern and eastern part of the state and covers an area somewhat as shown in Fig. 1. This region is bounded on the northeast by Pennsylvania and along

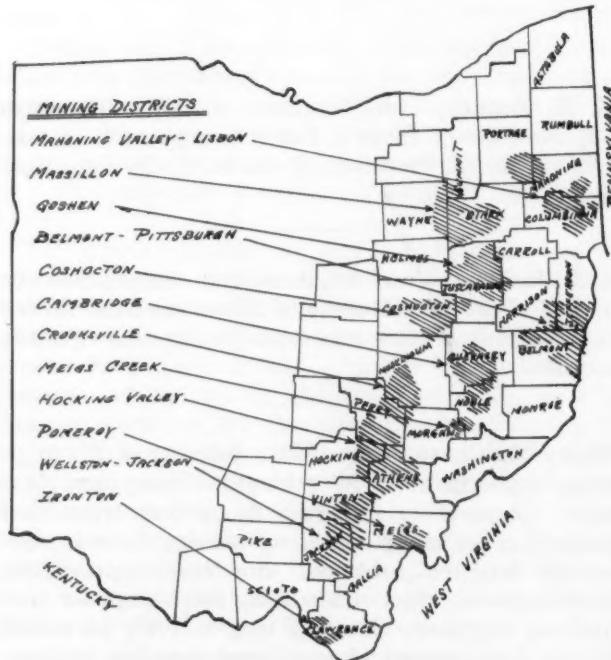


Fig. 1—Coal bearing regions of Ohio

the Ohio river by West Virginia and Eastern Kentucky, and is divided into a dozen or more mining districts, as shown. These districts are small areas of mining activity and, as a rule, assume the name of some town or city in the district.

Ohio produces four to five per cent of the bituminous coal mined in the United States and is the fifth largest producer as seen from Table I, which gives the five principal bituminous coal producing states and their relative production in recent years. Table II gives the relative production in the counties of the coal region

TABLE I  
PRINCIPAL COAL PRODUCING STATES IN THE UNITED STATES  
AND  
RELATIVE PRODUCTION IN RECENT YEARS  
IN  
PER CENT OF TOTAL BITUMINOUS PRODUCTION

STATE	1928	1929	1930	1931	1932
WEST VIRGINIA	26.5	25.9	26.0	26.5	27.7
PENNSYLVANIA	26.3	26.8	26.6	25.6	24.2
ILLINOIS	11.2	11.4	11.5	11.6	10.9
KENTUCKY	12.4	11.3	11.0	10.5	11.4
OHIO	3.1	4.4	4.8	5.4	4.5
	68.9	70.1	69.6	68.9	79.5

TABLE II  
RELATIVE PRODUCTION BY COUNTIES IN OHIO COAL REGION  
IN  
PER CENT OF TOTAL PRODUCTION OF STATE

COUNTY	1928	1929	1930	1931	1932
BELMONT	27.7	32.7	32.8	32.8	27.8
JEFFERSON	16.1	14.5	14.7	16.1	16.4
HARRISON	19.1	13.1	11.2	9.8	12.9
ATHENS	7.4	12.6	14.1	12.4	8.9
GUERNSEY	3.1	7.3	8.7	7.2	8.8
TUSCARAWAS	4.6	3.3	2.1	3.4	5.5
NOBLE	2.4	2.8	2.6	1.9	3.0
	80.4	86.3	86.2	79.8	83.3
APPROXIMATE PRODUCTION FOR STATE - MILLIONS OF TONS PER YEAR	15.6	23.7	22.6	20.4	13.9

of Ohio for the same period. About 75 to 80 per cent of the coal produced in the state is mined in five counties—Belmont, Jefferson, Harrison, Athens and Guernsey. Belmont, Jefferson and Harrison counties represent the Belmont-Pittsburgh district; Athens county is part of the Hocking Valley district; and Guernsey county is the major part of the Cambridge district. The Belmont-Pittsburgh district is by far the largest producer, yielding 55 to 60 per cent of the total production in the state.

The coals of Ohio belong to the Upper Pennsylvanian

and Lower Permian series of the Carboniferous Age and are found in five major formations as follows:

1. Washington, Dunkard, or upper barren (top)
2. Monongehela, or upper productive
3. Conemaugh, or lower barren
4. Alleghany, or lower productive
5. Pottsville, or conglomerate (bottom)

Table III gives an outline of these formations with the coal beds found in each, and the mining districts

TABLE III  
GEOLOGICAL ORDER OF COAL SEAMS IN OHIO  
AND  
MINING DISTRICTS OF PRINCIPAL BEDS

Geological Formation	Bed or Seam	Mining District or County of Principal Beds
Washington	Washington	
Monongehela	Waynesburg	
	Weig Creek Ohio No. 9	Weig Creek; Morgan, Noble, Monroe, Washington, Belmont, and Harrison counties.
	Pomeroy Redstone Ohio No. 8a	Pomeroy district in Weig county.
	Pittsburgh Ohio No. 8	Pittsburgh-Belmont; Belmont, Jefferson, Guernsey and Athens counties. Second in importance in state.
Conemaugh	Bethers town	
	Brush Creek	
Allegheny	Upper Freeport Ohio No. 7	Cambridge; Mahoning Valley; Massillon. Third in importance in state.
	Lower Freeport Ohio No. 6a	Pittsburgh-Belmont district in Jefferson county.
	Middle Kittanning Ohio No. 6	Hocking Valley; Goshen; Crooksville. Most important in state.
	Lower Kittanning Ohio No. 5	Lawrence, Jackson, Perry, Muskingum, and Mahoning counties.
	Clayton Ohio No. 4a	Wellston-Jackson; Vinton, Jackson and Lawrence counties.
	Brookville Ohio No. 4	
Pottsville	Upper Mercer Ohio No. 3a	Coshocton district.
	Lower Mercer Ohio No. 3	
	Quakertown Ohio No. 2	Wellston-Jackson district.
	Sharon Ohio No. 1	

of the principal beds. It is the custom in some states to number coal beds and in Ohio the beds are known by the number of their position in the geological order, beginning at the bottom. These numbers apply only to the beds within the state. Thus a Pittsburgh No. 8 coal is a coal from the Pittsburgh seam in Ohio.

Of the beds listed in Table III, the Middle Kittanning, or Ohio No. 6, and the Pittsburgh, or Ohio No. 8, beds are the two most important in the state. The Upper Freeport, or Ohio No. 7, bed is third in importance.

The Pittsburgh, or Ohio No. 8, bed is part of the Pittsburgh seam found in Pennsylvania, Maryland and West Virginia and is mined extensively in Belmont and Jefferson counties. The Ohio seam has higher ash, sulphur and volatile matter and lower total carbon and heat value than the Pennsylvania seam.

The Middle Kittanning, or Ohio No. 6, and the Upper Freeport, or Ohio No. 7, beds lie some 500 to 600 ft lower than the Pittsburgh bed and are part of the Kittanning and Freeport seams of Pennsylvania.

The Middle Kittanning bed is the most valuable in Ohio because of its quality and widespread quantity. It is mined in nearly every county of the coal region and is the principal product of the Hocking Valley district. It is easily ignited, burns freely and is excellent fuel for household and steam-generating purposes.

The Upper Freeport bed is the source of most of the coal produced in the Cambridge district. It is a moderately coking coal, suitable for locomotive and stationary boiler use.

Ohio coals, in general, can be burned on underfeed stokers or in pulverized form. The softening temperature of their ash is generally between 2200 and 2400 F. They contain too much sulphur for use in making coke and gas and are used chiefly for domestic, railroad and steam plant fuel. Most of the Ohio coal seams contain from 3 to 5 per cent sulphur. Low sulphur (1 to 2 per cent) coals are found in the following seams and counties.

Seam	County	Per cent Sulphur (Moisture and Ash Free)
Middle Kittanning	Hocking	1.9
Middle Kittanning	Athens	1.7
Middle Kittanning	Columbiana	1.9
Upper Freeport	Guernsey	1.9
Upper Freeport	Lawrence	1.9
Quakertown	Jackson	1.2

Coal analyses are usually reported on an "as-received" basis and often show a confusing variety of analytical values even for coals from the same bed and mine.

TABLE IV  
A. INDIVIDUAL ANALYSES OF PITTSBURGH COAL IN BELMONT COUNTY, OHIO  
(ABBREVIATED)

AS RECEIVED		MOISTURE AND ASH FREE							
MOISTURE	ASH	VOLATILE MATTER	FIXED CARBON	SULPHUR	HYDROGEN	CARBON	NITROGEN	OXYGEN	BTU/LB
2.8	9.4	43.2	56.8	5.8	5.6	79.5	1.2	7.9	14790
4.5	11.0	44.4	55.6	5.5	5.5	80.0	1.3	7.7	14640
3.4	7.9	41.5	58.5	3.3	5.4	80.5	1.4	9.4	14640
4.5	10.8	42.5	57.5	5.3	5.1	80.5	1.3	7.3	14660
3.9	8.5	45.2	54.8	3.9	5.5	81.3	1.5	7.8	14800
3 to 5	8 to 11	43.3	56.7	4.8	5.4	80.4	1.3	8.1	14705

B. INDIVIDUAL ANALYSES OF MIDDLE KITTANNING COAL FROM ATHENS COUNTY, OHIO  
(ABBREVIATED LIST)

6.7	6.8	40.9	59.1	2.6	5.5	80.5	1.4	10.5	14390
6.5	8.1	43.3	56.7	2.5	5.6	79.2	1.6	11.1	14360
6.2	7.8	42.3	57.7	1.1	5.5	80.5	1.5	11.4	14370
7.1	6.7	39.7	60.3	1.9	5.5	80.5	1.5	10.6	14340
7.3	6.7	37.7	62.3	1.0	5.4	80.8	1.6	11.2	14430
6 to 7½	6½ to 8	40.8	59.2	1.8	5.5	80.3	1.5	10.9	14380

TABLE V  
AVERAGE ANALYSES OF OHIO COALS

COUNTY AND SEAM	AS RECEIVED		MOISTURE AND ASH FREE							
	MOISTURE	ASH	VOLATILE MATTER	FIXED CARBON	SULPHUR	HYDROGEN	CARBON	NITROGEN	OXYGEN	BTU/LB
BELMONT - WASHINGTON	4-5	15-20	45.0	55.0	3.8	5.8	80.0	1.5	8.9	14450
BELMONT - WAYNESBURG	4-5	4-16	45.5	54.5	3.7	5.7	80.8	1.5	8.3	14590
BELMONT - MEIGS CREEK	3-5	10-17	42.9	57.1	4.1	5.4	80.5	1.3	8.7	14610
BELMONT - PITTSBURGH	3-5	8-12	43.2	56.8	4.7	5.4	80.5	1.3	8.1	14710
JEFFERSON - PITTSBURGH	4-5	5-10	41.3	58.7	3.1	5.5	81.6	1.5	8.3	14790
JEFFERSON - LOWER FREEPORT	3-4	7-9	42.0	58.0	2.9	5.6	82.3	1.6	7.6	14940
JEFFERSON - MIDDLE KITTANING	2-3	9-12	42.6	57.4	2.4	5.8	82.4	1.7	7.7	14950
HARRISON - MEIGS CREEK	4-6	10-12	40.9	59.1	3.8	5.5	81.4	1.5	7.8	14595
ATHENS - PITTSBURGH	5-7	8-10	42.8	57.2	4.5	5.2	79.2	1.1	10.0	14280
ATHENS - MIDDLE KITTANING	5-7	7-10	40.4	59.6	1.7	5.5	80.3	1.5	11.0	14360
GUERNSEY - PITTSBURGH	4-5	8-9	47.4	52.6	5.6	5.6	79.8	1.5	7.5	14630
GUERNSEY - BAKERSTOWN	4-5	10-11	47.2	52.8	4.4	5.7	80.1	1.8	8.0	14650
GUERNSEY - UPPER FREEPORT	3-7	5-8	40.0	60.0	1.9	5.5	82.4	1.6	8.5	14650
TUSCARAWAS - MIDDLE KITTANING	3-5	5-8	45.0	55.0	4.3	5.6	79.4	1.5	9.2	14495
NOBLE - MEIGS CREEK	3-5	10-13	46.2	53.8	5.7	5.6	79.2	1.2	8.3	14550
NOBLE - UPPER FREEPORT	5-7	7-9	42.4	57.6	2.8	5.6	81.7	1.7	8.2	14650
HOCKING - MIDDLE KITTANING	6-9	5-8	41.5	58.5	1.9	5.5	80.2	1.5	10.9	14425
PERRY - MIDDLE KITTANING	5-7	5-10	44.1	55.9	3.6	5.6	79.0	1.5	10.3	14365
PERRY - LOWER KITTANING	6-7	7-10	42.7	57.3	4.3	5.5	78.7	1.4	10.1	14345
MUSKINGUM - UPPER FREEPORT	4-9	7-12	48.2	51.8	5.2	5.6	78.4	1.4	9.4	14390
MUSKINGUM - MIDDLE KITTANING	4-6	4-10	48.1	51.9	4.8	5.6	78.3	1.4	9.9	14425
MUSKINGUM - LOWER KITTANING	5-8	6-9	46.0	54.0	5.4	5.5	78.5	1.5	9.1	14400
MEIGS - POMEROY	5-8	8-11	41.7	58.3	2.8	5.5	79.3	1.3	11.1	14370
COLUMBIANA - UPPER FREEPORT	3-4	7-11	42.6	57.4	3.9	5.7	82.6	1.8	6.0	14970
COLUMBIANA - LOWER FREEPORT	3-6	10-12	42.2	57.8	3.5	5.7	82.1	1.7	7.0	14810
COLUMBIANA - MIDDLE KITTANING	3-5	5-10	40.1	59.9	1.9	5.5	83.7	1.6	7.3	15070
JACKSON - LOWER KITTANING	8-9	7-8	41.8	58.2	3.1	5.4	79.1	1.6	10.8	14480
JACKSON - CLARION	5-6	8-12	46.3	53.7	5.0	5.6	77.3	1.5	10.6	14275
JACKSON - QUAKERTOWN	7-9	2-5	38.3	61.7	1.2	5.2	81.0	1.6	11.0	14200

TABLE VI  
AVERAGE ANALYSES OF PRINCIPAL SEAMS  
IN DIFFERENT COUNTIES

SEAM AND COUNTY	AS RECEIVED		MOISTURE AND ASH FREE							
	MOISTURE	ASH	VOLATILE MATTER	FIXED CARBON	SULPHUR	HYDROGEN	CARBON	NITROGEN	OXYGEN	BTU/LB
PITTSBURGH NO. 5										
BELMONT	3-5	8-12	43.2	56.8	4.7	5.4	80.5	1.3	8.1	14710
JEFFERSON	4-5	5-10	41.3	58.7	3.1	5.5	81.6	1.5	8.3	14790
GUERNSEY	4-5	8-9	47.4	52.6	5.6	5.6	79.8	1.5	7.5	14630
ATHENS	5-7	8-10	42.8	57.2	4.5	5.2	79.2	1.1	10.0	14280
MIDDLE KITTANING NO. 6										
COLUMBIANA	3-5	5-10	40.1	59.9	1.9	5.5	83.7	1.6	7.3	15070
STARK	5-7	8-10	44.1	55.9	4.0	5.4	80.2	1.4	9.0	14710
CARROLL	3-4	6-7	43.7	56.3	3.4	5.5	80.5	1.6	9.0	14570
TUSCARAWAS	3-5	5-8	45.0	55.0	4.3	5.6	79.4	1.5	9.2	14495
JEFFERSON	2-3	11-12	42.6	57.4	2.4	5.8	82.4	1.7	7.7	14950
COSHOCOTON	4-5	6-10	44.7	55.3	4.8	5.5	78.7	1.4	9.6	14400
MUSKINGUM	4-6	4-10	48.1	51.9	4.8	5.6	78.3	1.4	9.9	14425
PERRY	5-7	5-10	44.1	55.9	3.6	5.6	79.0	1.5	10.3	14365
ATHENS	5-7	7-10	40.4	59.6	1.7	5.5	80.3	1.5	11.0	14360
HOCKING	6-9	5-8	41.5	58.5	1.9	5.5	80.2	1.5	10.9	14425
UPPER FREEPORT NO. 7										
COLUMBIANA	3-4	7-11	42.6	57.4	3.9	5.7	82.6	1.8	6.0	14970
GUERNSEY	3-7	5-8	40.0	60.0	1.9	5.5	82.4	1.6	8.6	14650
NOBLE	5-7	7-9	42.4	57.6	2.8	5.6	81.7	1.7	8.2	14650
MUSKINGUM	4-9	7-12	48.2	51.8	5.2	5.6	78.4	1.4	9.4	14390
LAWRENCE	7-9	8-11	39.2	60.8	1.9	5.3	80.0	1.6	11.2	14320
MEIGS CREEK NO. 9										
HARRISON	4-6	10-12	40.9	59.1	3.8	5.5	81.4	1.5	7.8	14595
BELMONT	3-5	10-17	42.9	57.1	4.1	5.4	80.5	1.3	8.7	14610
NOBLE	3-5	10-13	46.2	53.8	5.7	5.6	79.2	1.2	8.3	14550
MORGAN	4-5	10-11	44.4	55.6	5.5	5.5	78.4	1.1	9.5	14315
WASHINGTON	3-4	9-13	44.0	56.0	6.2	5.6	78.4	1.1	8.7	14595

Most of these variations are due to the variable amounts of moisture and ash mixed with the coal substance and if the analyses are calculated to a moisture and ash-free basis, it is generally true that the composition of the coal substance is fairly constant for coals from the same mine. An average of many such analyses will give a basic analysis of the coal substance from which complete proximate and ultimate analyses can be set up for coals of any moisture and ash content. The moisture and

range of values in such lists and the possible error involved in the averaging of them.

Table V gives the average analyses for coals from the principal seams in the principal counties and shows the variations in the analyses of different coals within the same area. Where more than one coal seam is listed, the analyses are in geological order as given in Table III. The same averages, arranged to show the variations in the analyses for the same seam in different counties, are given in Table VI. In this table, where more than one county is listed, the order is in general from northeast to southwest. Only the principal producing seams and counties have been considered.

The analyses of coals from different seams within the same area are generally, more similar than the analyses of coals from the same seam in different areas. The wide variation in the composition of the coal substance of the Pittsburgh seam in different states and counties is evident in the following moisture and ash-free analytical values:

	Maximum	Minimum	Average
As Received			
Moisture	9.0	2.0	5.0
Ash	20.0	4.0	9.0
Moisture and Ash Free			
Volatile Matter	48.2	38.3	43.1
Fixed Carbon	51.8	51.8	56.9
Sulphur	6.2	1.2	3.7
Hydrogen	5.5	5.2	5.5
Carbon	83.7	76.9	80.7
Nitrogen	1.5	1.1	1.5
Oxygen	11.2	6.0	8.6
Btu per lb	15070	14185	14575
Moisture & Ash Free	Moisture Free or Dry	As Received	
Proximate			
Moisture	-	9.47	9.0
Ash	-	39.02	37.07
Volatile Matter	43.1	51.51	48.93
Fixed Carbon	56.9	100.00	100.00
Ultimate			
Sulphur	3.7	3.35	3.18
Hydrogen	5.5	4.98	4.73
Carbon	80.7	73.05	69.41
Nitrogen	1.5	1.36	1.29
Oxygen	8.6	7.78	7.32
Btu per lb	14575	13195	12535

ash in a coal are generally known or may be readily determined in any small chemical laboratory but a complete analysis and heat value can be determined accurately only by an experienced coal chemist in a well equipped laboratory. In the absence of a specific analysis, one set-up from these averages will be sufficiently accurate for most purposes and will serve as a check on a given analysis.

Table IV is an abbreviated list of individual analyses of coals from the Pittsburgh bed in Belmont county and from the Middle Kittanning bed in Athens county. The analyses are not selected and show the normal

County	State	Volatile Matter	Sulphur	Total Carbon	Oxygen	Btu/lb
Athens	Ohio	42.8	4.5	79.2	10.0	14280
Jefferson	Ohio	41.3	3.1	81.6	8.3	14790
Alleghany	Penna.	38.4	1.3	84.2	7.4	15090
Fayette	Penna.	36.6	1.6	85.2	5.9	15275
Harrison	W. Va.	43.3	3.5	83.4	6.1	15375
Ohio	W. Va.	46.5	4.0	81.9	6.4	14845
Mineral	W. Va.	18.9	1.2	89.7	2.7	15720
Alleghany	Md.	18.8	1.1	89.2	2.9	15660

The determination of the average analysis of a coal from a given county involves the averaging of the average analyses of the several seams that are mined in that area. From Table V it is seen that the coals from the principal seams in Belmont county are sufficiently similar in composition to justify averaging to give a typical analysis for a Belmont county coal. The same is true for Jefferson, Perry and Muskingum counties. Jackson county and Guernsey counties, on the other hand, produce coals from three seams of quite different composition and the use of an average analysis of these seams would not be justified except in cases when the name of the particular seam in the county is not known.

The extent to which averaging may be carried, depends on the degree of accuracy desired. Too much emphasis cannot be placed on the desirability of knowing

TABLE VIII  
ANALYSES OF TYPICAL OHIO COALS

SEAM	AS RECEIVED						> M & A FREE <		
	M	A	V.M.	F.G.	S	Btu	V.M.	Btu	
MIDDLE KITTANNING-OHIO No 6	5.6	7.7	37.2	49.5	3.5	12500	42.9	14420	
PIITSBURGH-OHIO No 8	4.8	9.1	36.3	49.8	3.8	12560	42.2	14600	
UPPER FREEPORT-OHIO No 7	6.5	7.0	36.0	50.5	2.0	12600	41.6	14560	
LOWER FREEPORT-OHIO No 6b	3.8	7.1	37.0	52.1	2.5	13320	41.5	14940	
LOWER KITTANNING-OHIO No 5	5.0	8.6	38.0	48.4	3.3	12800	44.0	14820	
MEIGS CREEK-OHIO No 9	4.0	11.5	36.0	48.5	4.3	12250	42.6	14500	
REDSTONE-OHIO No 8a	6.7	10.5	35.0	47.8	2.4	11875	42.3	14350	
CLARION-OHIO No 4a	6.0	11.5	39.0	43.5	4.8	11980	47.3	14540	
BROOKVILLE-OHIO No 4	5.3	10.7	39.0	45.0	4.3	12200	46.4	14520	
AVERAGE	5.3	9.3	37.1	48.3	3.4	12455	43.4	14600	

Note: The above typical analyses taken from Keystone Coal Catalogue

the source of a coal, not only the state and county from which it comes, but also the seam and mine from which it is taken. If the only information available is that the coal comes from Ohio, an average analysis of coals from all counties, more or less weighted on a production basis, may be used without serious error. Such an analysis cannot be set up for most states because of the variety of coals involved, but in Ohio the bulk of the coal produced is fairly uniform in composition. Such an average analysis is given in Table VII with maximum and minimum values for the state. The "as-received"

TABLE IX  
IDENTIFICATION OF COMMON TRADE NAMES FOR OHIO COALS  
(abbreviated list)

Trade Name	Coal Seam or Bed	County or District
Alexander	Upper Freeport - No 7	Muskingum
Big Vein	Upper Freeport - No 7	Carroll
Black Bend	Upper Freeport - No 7	Stark & Tuscarawas
Black Bed	Middle Kittanning - No 6	
Blue Limestone	Lower Mercer - No 3	
Blue Rock	Upper Freeport - No 7	Muskingum
Brier Hill	Sheron - No 1	
Cambridge	Upper Freeport - No 7	Cambridge
Cerbondale	Middle Kittanning - No 6	Athens
Chey Vein	Lower Kittanning - No 5	
Chestnut	Middle Kittanning - No 6	Coshocton
Creek Vein	Lower Kittanning - No 5	Tuscarawas
Dennison	Middle Kittanning - No 6	Columbiana
Dry Run	Middle Kittanning - No 6	Morgan & Athens
Federal Creek	Pittsburgh - No 8	
Flint Ridge	Lower Mercer - No 3	
Great Vein	Middle Kittanning - No 6	Hocking Valley
Heiden Furnace	Lower Freeport - No 6	Vinton
Hammonville	Lower Kittanning - No 5	Jefferson
Hammonville Strip	Middle Kittanning - No 6	Jefferson
Hatcher	Lower Freeport - No 6	Lawrence
Hocking	Middle Kittanning - No 6	Hocking Valley
Jackson Hill	Quakertown - No 2	
Loetonia	Lower Kittanning - No 5	Columbiana
Limestone	Glorion - No 4a	Wellston-Jackson
Lower New Lexington	Lower Kittanning - No 5	Perry
Mineral City	Middle Kittanning - No 6	Tuscarawas
Mineral Point	Lower Kittanning - No 5	
Nelsonville	Middle Kittanning - No 6	Stark
New Castle	Lower Kittanning - No 5	Palmyra
Ossenburg	Middle Kittanning - No 6	
Palmyra	Sharon - No 1	Tuscarawas
Pikes Run	Middle Kittanning - No 6	
Potters Vein	Lower Kittanning - No 5	
Redstone	Pomeroy - No 8a	Meigs
Sedalia	Upper Freeport - No 7	Athens
Sheridan	Middle Kittanning - No 6	
Steubenville Sheet	Lower Freeport - No 6	Jefferson
Straitsville	Middle Kittanning - No 6	Perry
Sunday Creek	Middle Kittanning - No 6	Hocking Valley
Up per Zeleski	Middle Kittanning - No 6	Vinton
Upper Zanesville	Middle Kittanning - No 6	Muskingum
Washington Furnace	Middle Kittanning - No 6	Washington
Waterloo	Upper Freeport - No 7	Gallia
Wellston	Quakerstown - No 2	Jackson
Whan	Lower Freeport - No 6a	Lisbon
Wilber	Lower Mercer - No 3	

and "dry" analyses are calculated to a basis of 5 per cent moisture and 9 per cent ash. These moisture and ash values are for mine samples and may not be typical of delivered coal after cleaning, sizing, washing or weathering.

Coal analyses are converted from one basis to another by use of the following equations. Charts to facilitate conversion were prepared and published in a recent issue of COMBUSTION.<sup>1</sup>

- [Moisture & Ash Free]  $\times [1 - (m + a)]$  = As received
- [Dry]  $\times [1 - m]$  = As received  
*m* and *a* are percentages of moisture and ash on an *as-received basis* expressed as decimals
- [Moisture & Ash Free]  $\times [1 - a]$  = Dry  
*a* is percentage of ash on a *dry basis* expressed as a decimal.

Table VIII gives a list of proximate analyses, on an as-received basis, of typical Ohio coals as given in a Keystone Coal Catalog. The volatile matter and heat value have been calculated to a moisture and ash-free basis and show good agreement with the averages given in Tables V, VI and VII.

<sup>1</sup> October, 1934.

The great variety of trade names for Ohio coals tends to confuse identification of a coal when the name of the seam or county from which it comes, is not given. Some of the common names for Ohio coals are given in Table IX with seam and county identification. Some of the names apply only to coals within a county; for example, Hamden Furnace coal is Lower Freeport, or Ohio No. 6a coal in Vinton county. Others apply to mining districts; as Cambridge coal is Upper Freeport, or Ohio No. 7 coal in the Cambridge district. Still others apply to the whole state; as Pittsburgh No. 8 is the Pittsburgh seam in Ohio. This list is only a partial one and is given to show the great variety of names and labels that coals may have even though they may be very similar in composition and character. In most cases these trade names are local names of towns, cities, creeks, etc., and if they can be located on a map, the county or area from which they came can be determined and the analysis of the coal set up. Some of the trade names are identical with names of coals in other states, so care should be used. For example, Big Vein is also the name given to the Pittsburgh seam in the Georges Creek district in Maryland.

## Central Station Statistics

(Released Oct. 13 by the Edison Electric Institute)

	1934	1933
Production for 12 months ending August 31, 1934, kw hr generated:		
Fuel	52,855,819,000	45,783,393,000
Hydro	30,377,995,000	31,624,803,000
Total	83,233,814,000	77,408,196,000
Gross revenue 2 per cent over the same period for 1933		
	1934	1933
Per cent generated by water power	36.5	40.9
Lb coal per kw hr	1.45	1.46
Ave. annual consumption per customer, kw hr	621	601
Ave. revenue per kw hr, cents	5.35	5.54
Generating capacity, kw:		
Steam	23,913,900	24,025,800
Hydro	9,006,600	8,975,300
Int. comb.	468,100	461,700
Total	33,388,600	33,462,800
Total number of customers	24,641,129	24,020,532
Number of commercial and large light and power customers	530,413	528,383

## 34 Billion Revolutions

The performance records of a turbine-generator installed in the Union Stock Yards power plant of Armour & Company, Chicago packers, indicate that it has more than 34 billion revolutions to its credit. The turbine is a G. E. machine rated 1250 kw and has been whirling away at 3600 rpm on a practically uninterrupted 24-hour-a-day schedule ever since it was first placed in service in 1916. With the exception of two brief pauses for reblading and those necessary for the annual inspections, the equipment has never been shut down.

# Slag Bottom Furnace Experiences at Hell Gate Station\*

Following an experimental installation at the Sherman Creek Station, three pulverized coal fired boiler units were installed at Hell Gate Station, two of the dry bottom type and the third arranged for continuous slagging. Under the conditions obtaining at this station the continuous slagging type proved the more satisfactory, especially after provision had been made for air cooling the bottom and water cooling the slag ring. The two latest boilers at Hell Gate have slag-tap furnaces and experiences with these also related. Advantages of the slagging type of furnace are summarized.

HERE are two general types of slag bottom furnaces in operation at Hell Gate Station. In one of these the slag drains almost continuously while in the other slag tapping is a periodic operation for which the furnace conditions must be set preliminary to tapping off the accumulated slag.

Before describing the essential features and operating characteristics of the two types it may be of interest to refer briefly to some of the experimental work at Sherman Creek Station which led up to the development of the continuous slag tap design.

During 1924 and 1925 the United Electric Light and Power Company carried out a great many experiments at Sherman Creek Station with various types of powdered coal burners. It was observed at that time that those burners which produced the highest combustion efficiencies also developed the highest furnace temperatures and in those cases a great deal of trouble was encountered with molten ash or slag which accumulated in the furnace bottom.

One of the most interesting of the experimental burners was the Fuller-Lehigh Well-Type Burner in which heat liberating rates, in excess of 300,000 Btu per cu ft of well volume were obtained. It was possible to operate with CO<sub>2</sub> higher than 16 per cent without excessive carbon loss but because of the intense burning rates with temperatures reaching 2850 F slag was built up in the wells which choked up some of the coal entrance pipes. Efforts made to project the intense burning out into the furnace by raising secondary air pressures merely transferred the slag problem to the furnace proper. Frequent outages were necessary to drill out the accumulated slag which involved a great deal of labor as well as destruction of refractories.

To overcome this troublesome condition without lowering CO<sub>2</sub> rates to inefficient levels an experimental slag-

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tap design was worked out which was the forerunner of the continuous slag tap furnace at Hell Gate Station.

Fig. 1 shows the experimental design first tried out on boiler No. 10 at Sherman Creek Station. Note the round slag port in the center of the furnace bottom with the ring projecting up above the furnace bottom to form a dam, thus avoiding the movement of slag in contact with the floor refractories and its erosive effects. A cylindrical discharge chamber led down to a water hopper which served as a gas seal and also as a chilling agent for breaking up the slag.

The discharge pipe was provided with two observation ports and also a draft duct. The suction of the draft

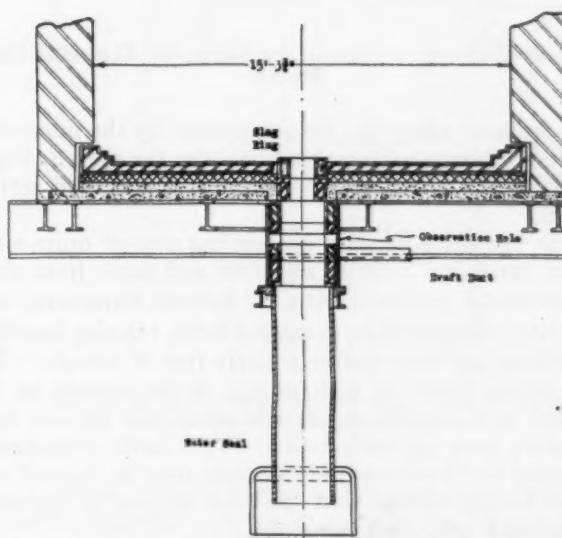


Fig. 1—Experimental slag-tap furnace under boiler No. 10 at Sherman Creek Station

duct served not only to absorb air infiltration but also to draw hot furnace gas down through the slag port when the slag was sluggish.

When the eighth row of boilers was laid out for Hell Gate it was considered necessary to develop a capacity of four hundred thousand pounds of steam per hour from each of the three boilers. Tangentially-fired powdered-coal burners by Combustion Engineering Company were selected and the four walls of the furnace were cooled by fin-tube water walls.

Because of the limited space in which these capacities were to be developed and the lack of experience at that time with completely water-cooled furnace walls, the

\* Presented at Power Session of Metropolitan Section, American Society of Mechanical Engineers, New York, October 24, 1934.

three furnace bottoms differed in the following respects. Boiler No. 81 had a refractory-lined hopper bottom and water-screen tubes to check slag formation. Boiler No. 82 had a similar hopper bottom and the screen tubes were omitted pending operating experience. Both furnaces had hydraulically operated gates in the hopper bottoms to permit access for ash removal. Boiler No. 83 was equipped with a slag bottom designed for continuous

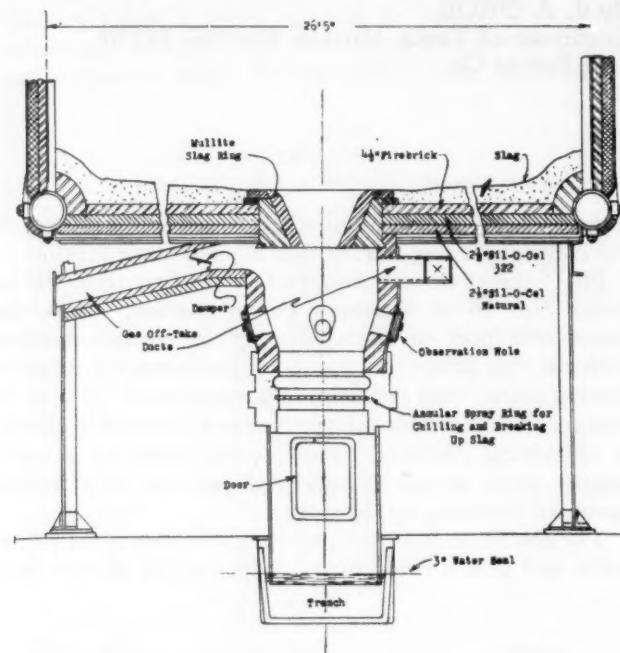


Fig. 2—Slag-tap furnace under boiler No. 83 at Hell Gate Station

slag drainage along the lines suggested by the pioneering work at Sherman Creek Station; see the sketch, Fig. 2 showing arrangements for granulating slag and jetting trench.

The operation of slag tapping has proved quite automatic involving little or no labor and aside from some maintenance problems with the bottom refractories and slag ring, which will be discussed later, the slag handling operation has been almost entirely free of trouble. The slag drains freely at high ratings, stops entirely at low ratings and resumes again whenever the furnace temperature goes up with rating. Very little attention is required and a wide variety of coals may be burned with equal facility except that the ratio of slag to fly ash is diminished with high fusion ash.

By comparison, the two dry-bottom furnaces have caused much more operating inconvenience and use of

labor because of the layers of ash and slag which form on the bottom. If it were not for widely fluctuating ratings it is likely that the furnace equipped with the water screen would avoid slag to a large degree. The ash removal operation on the dry-bottom furnaces requires six or eight men for twelve hours almost weekly for each furnace.

Aside from labor saving the presence of a hot molten pool in the slag bottom furnace adds flame stability to the combustion conditions. Violent load changes and excessively lean mixtures have occasionally caused the flame to puff out on the dry bottom furnaces with some damage to arches and wall covering. This does not occur with the slag bottom furnace and consequently the explosion hazard is greatly reduced.

The maintenance troubles which were encountered in this furnace during the first few years of operation were with the refractory bottom and the refractory slag ring. The best of the refractory slag rings were made of a high grade of mullite and with constant patching lasted about  $5\frac{1}{2}$  months. The trouble invariably started with the plastic material, which joined the ring sections, washing out and thus forming a groove. This lowered the slag level in the furnace and exposed the furnace floor refractories to the punishment of high temperature and slag erosion and at such a time the bottom casings and beams would tend to overheat. It was necessary to rebuild the furnace bottom in about 13 months.

The solution to furnace bottom maintenance was accomplished by air cooling. Fig. 3 indicates the general arrangement. Old boiler tubes laid in grout served as conduits for the cooling air. Moldite A was placed above the tubes and because of the dyke construction of the slag ring it was necessary to weight load the refractory blocks to avoid floating. This was done by putting in nine inches of dolomite and several inches of crushed slag.

This air-cooled bottom has been in operation for about two years with no maintenance and from all indications will last many years.

The refractory slag ring still formed a weak link until a water-cooled ring coil was worked out as shown in Fig. 4. This has been giving satisfactory service. The amount of heat transferred to the cooling water is 130,000 Btu per hr.

In the last boiler house extension two boilers of a capacity of 1,000,000 lb of steam per hour were installed. These boilers were entirely B&W with powdered coal slag-bottom furnaces. The bottom was air cooled and has proved highly satisfactory from the maintenance standpoint. Chromous ore is used for passage of

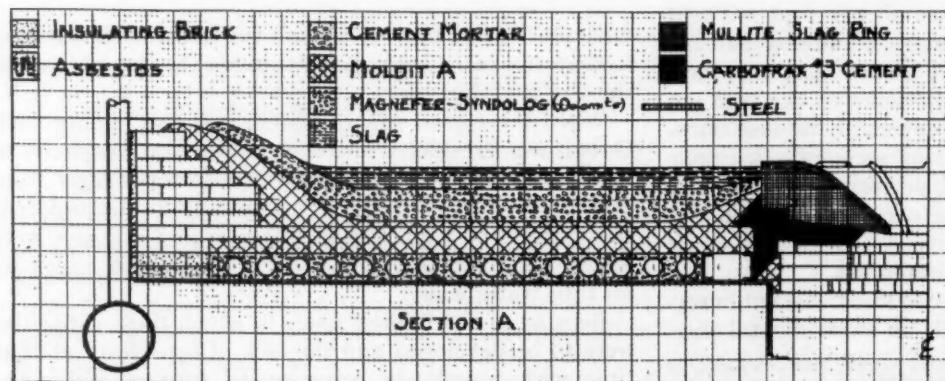


Fig. 3—Arrangement for air cooling the continuous slagging furnace at Hell Gate

cooling air and pounded magnesite grout forms the bed upon which the slag forms.

The slag tapping operation is performed about twice a week and usually requires about six or eight hours. When the furnace is set for slagging the flame is directed against the floor and the furnace is placed under a slight positive pressure. The slag port gate is opened hydraulically and the crust is poked clear. The slag then starts to drain out over the slag spout into a disintegrating chamber where high velocity water jets under 200 lb pressure break the slag up into fine size suitable for conveyance through the ash sluicing system.

#### *Difficulties with Slag Tapping*

During the first year of operation a great deal of difficulty was experienced with slag tapping due to the sluggishness of the slag mass which chilled at the port and involved considerable chipping and poking.

It was frequently necessary to run the boiler at ratings of 700,000 to 800,000 lb per hour to develop enough temperature to enable the slag to flow and constant poking and chipping was necessary. Experiments were conducted with fluxes, such as fluorspar and soda ash, which was introduced several hours before tapping. This enabled operation at lower ratings during the tapping period but the injection of fluxes was considered a nuisance. Coals having an ash-fusion temperature of 2500 F or higher caused tapping to be a very inconvenient, laborious process involving excessively high ratings and constant poking. While it was known that the influence of the water walls in proximity to the slag ports on the sides of the furnace would tend to lower the temperature of the slag mass it was believed that air infiltration through the slag port was more of a factor. To test the influence of this factor the slag port on the south wall of boiler No. 91 was boxed in with a sealing chamber and equipped with a draft duct. The first time this was tried out the slag drained so freely and abundantly that it threatened to plug up the sluiceways until the operators learned to make use of the check damper on the draft duct.

It was possible to tap from this port at ratings lower than 400,000 lb per hour with virtually no poking or chipping even with high-fusion coals while at the same time no slag could be drawn from the port on the opposite wall without raising the rating.

In the past year or two the fusion temperature of our coal has gone down to about 2325 deg and there is now no special difficulty in slag tapping from any of the ports even at steaming ratings below 500,000 lb per hr. Improvements in the technique of slag tapping, such as placing the furnace under a pressure and elevating the CO<sub>2</sub>, have contributed to the greater ease of tapping.

#### *Monel water-jacketed slag spouts*

From the maintenance standpoint the use of cast-iron slag spouts on the two ninth row boilers proved unsatisfactory as the slag adhered to the iron and solidified, forming a barrier to slag flow. The present slag spouts are of monel metal water jacketed and the slag sheds easily from the spout surfaces. Occasional leaks occur in the upper corners of the spouts requiring brazing but it is believed this can be overcome by improving the circulation of the cooling water.

Fly ash from various shelving hoppers in the boiler circuit is now drained into the furnace for disposal by slagging. It is not difficult to get rid of heavy dense slag but it might be a problem to dispose of light fly ash if it were not for the convenience of slagging the fly ash.

Another advantage, from the dust elimination standpoint, is the fact that upwards of 40 per cent of the ash settles out in the furnace and is slagged while only about ten per cent of the ash settles out in our dry bottom furnaces. This reduces the burden on the cinder catcher by lowering the dust loading and also puts the ash in form easy to dispose. Dense slagged ash weighs about 140 lb per cu ft. It is easy to trap in our ash-reclaiming pits

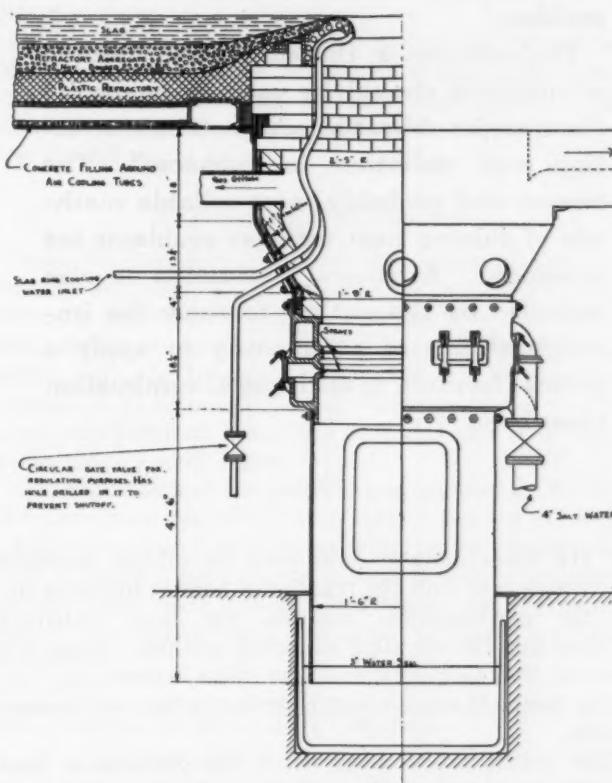


Fig. 4—Showing how water-cooled slag ring is installed in the continuous slagging furnace

and, mixed with stoker cinder makes excellent aggregate for cinder concrete. It is also suitable for fill purposes when there is opportunity for such use.

Fly ash, on the other hand, is difficult to dispose of due to its extreme fineness and difficulty of transport. It is unsuitable for fill due to light weight of the tiny hollow spheres and when wet the material behaves very much like quicksand.

#### *Advantages of Slag Bottom Furnaces*

Some of the benefits of the slag bottom furnaces at Hell Gate may therefore be summarized briefly as follows:

Labor saving in ash disposal.

Convenient disposal of fly ash dust to slag furnace.

Improved flame stability with lessened explosion hazards.

Wider choice of fuels.

Operation at higher CO<sub>2</sub> levels.

# Heat Transfer in Combustion Chambers

By G. A. HAWKINS

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Many theories have been suggested to account for the transmission of heat in a combustion chamber, but no one analysis leads to a general rational solution of the problem.

The question is, therefore, what method or methods should be used in analyzing the transfer of heat by conduction, convection and radiation in furnaces? The newest and probably most reliable methods of solving heat transfer problems are presented. A general discussion is also included by the author to show the impracticability of attempting to apply a general formula to all types of combustion chambers.

THE three methods now used for solving problems which deal with the transfer of heat in furnaces are: the mathematical analysis, the heat exchanger method and the so-called empirical method. Some will contend that no clear distinction exists between any two of the methods cited, which is probably the case to some extent.

The mathematical analysis of the problem of heat transfer by means of the various mechanisms in a combustion chamber leads to results which are very complicated, and in all probability are only fairly reliable. McAdams<sup>1</sup> develops the following general equations for the total heat given up by the flame, and the temperature of the refractory:

$$q = \rho_c \cdot \rho_F \cdot 0.172 \cdot \left[ A_{CF} + A_{RF} \frac{1}{1 + \left( \frac{\rho_F}{1 - \rho_F} \right) \left( \frac{A_{RF}}{A_R \cdot F_R} \right)} \right] \left[ \left( \frac{T_F}{100} \right)^4 - \left( \frac{T_c}{100} \right)^4 \right] + q_{CC} + q_{CR} \dots \dots \dots (1)$$

$$T_R = T_c \sqrt{\frac{\left( \frac{T_F}{T_c} \right)^4 + \left( \frac{1 - \rho_F}{\rho_F} \right) \cdot \left( \frac{A_R \cdot F_R}{A_{RF}} \right)}{1 + \left( \frac{1 - \rho_F}{\rho_F} \right) \cdot \left( \frac{A_R \cdot F_R}{A_{RF}} \right)}} \dots \dots \dots (2)$$

where,  $\rho_c$  = net emissivity of (cold) surface and is equal to the actual emissivity if the surface is plane. It approaches unity if it is a bank of tubes.

$\rho_F$  = emissivity of the flame due to all constituents in it.

<sup>1</sup> McAdams, W. H., "Heat Transmission," (New York: McGraw Hill Book Co., 1933).

$A_{CF}$  = that portion of the flame directed toward the cold surface.

$A_{RF}$  = that portion of the flame directed toward the refractory surface.

$A_R$  = refractory surface area.

$F_R$  = area factor.

$T_F$  = average flame temperature.

$T_c$  = average refractory temperature.

$q_{CC}$  = Btu/hr to cold surface by convection, at only those cold surfaces which affect the average flame temperature in the combustion space.

$q_{CR}$  = Convection heat transferred to the refractory.

For the complete derivations of these equations one should consult the original reference.

The method of analysis of heat transfer in industrial furnaces and equipment, by means of considering such equipment as heat exchangers, has been treated by Schack.<sup>2</sup> In this work he points out the fact that nearly all problems dealing with heat transfer in industrial furnaces may be calculated by using the fundamental equations for heat exchangers. The difficulty in applying this method is in the determination of the transmittance or conductance. By transmittance is meant the overall heat transfer coefficient and by conductance the film-coefficient. The equations for the total heat transfer to one square foot of heating surface, and the relation between the relative blackness of the gas and the furnace temperature are presented to show the types used in the heat exchanger method of analysis.

$$q = \left[ \left( \frac{T_w}{100} \right)^4 - \left( \frac{T'}{100} \right)^4 \right] [C_1 + C_2 (1 - b)] + 4(t - t') \dots \dots \dots (3)$$

Total

$$b = \frac{1}{1 + \frac{C_1 A_{SEC} \left[ \left( \frac{T}{100} \right)^4 - \left( \frac{T_w}{100} \right)^4 \right]}{C_2 A \left[ \left( \frac{T_w}{100} \right)^4 - \left( \frac{T'}{100} \right)^4 \right]} - \frac{h_c(t - t_w) - q_L}{C_1 \left[ \left( \frac{T}{100} \right)^4 - \left( \frac{T_w}{100} \right)^4 \right] + C_2 \frac{A}{A_{SEC}} \left[ \left( \frac{T_w}{100} \right)^4 - \left( \frac{T'}{100} \right)^4 \right]}} \dots \dots \dots (4)$$

For special cases equation (4) reduces to the following form:

$$b = \frac{\left( \frac{T_w}{T'} \right)^4 - 1}{\left( \frac{T}{T'} \right)^4 - 1} \dots \dots \dots (5)$$

<sup>2</sup> Schack, A. (Translated from the German by H. Goldschmidt and E. P. Partridge) "Industrial Heat Transfer," (New York: John Wiley and Sons, 1933).

The terms appearing in these equations have the following meanings:

$T$ ,  $t$  = temperature of the gas stream in the section of the furnace under consideration,  $R^*$ ,  $F$ .

$T_w$ ,  $t_w$  = inner surface temperature of the secondary heating surfaces,  $R$ ,  $F$ .

$T'$ ,  $t'$  = temperature of the direct heating surface  $R$ ,  $F$ .

$C_1$  = radiation constant of the brick surface to the gas.

$C_2$  = radiation constant of the brick surface to the furnace charge.

$C_3$  = radiation constant of the furnace charge to the gas.

$h_c$  = surface conductance by convection.

$A$  = direct heating surfaces.

$A_{ss}$  = secondary heating surfaces.

$q_L$  = heat lost by conduction to the outside.

For a complete discussion of the subject of heat transfer calculations in furnaces by the method of heat exchangers the original should be consulted.

The method of heat transfer analysis by an empirical means seems to be the best suited for the purpose of calculation at the present time, as one and only one equation can be applied to one and only one particular type of furnace. This solution calls for the collection of data and the development of an empirical formula based on the collected data. Orrok<sup>3</sup> developed the following equation for determining the fraction of heat which is transmitted to the heat receiving surface:

$$u = \frac{1}{1 + \frac{G \sqrt{C_0}}{27}} \dots \dots \dots (6)$$

In this equation

$G$  = the ratio of air to fuel by weight.

$C_0$  = specific firing rate.

Numerous investigators have developed similar formulas to express the transfer of heat within a furnace.

It is evident that there is no general rational method for subdividing the heat transfer in a boiler furnace into the three component parts, radiation, convection and conduction.

The following discussion shows the impracticability of using either the first or second method for obtaining the solutions of heat transfer problems in furnaces. No one equation can be set up and used as a general equation for all problems dealing with the transfer of heat in a boiler furnace.

Each particular type of fuel presents a distinct problem in heat transfer analysis. A coal-burning furnace does not behave in the same manner as does a gas-fired furnace, insofar as heat transfer is concerned. Therefore, the subject of fuels introduces a variable into the already complex problem.

Considering the flame used in the combustion process, is it possible to compare the radiation coming from a non-luminous gas flame with a glowing coal bed? The use of non-luminous vs. luminous flames is a disputed question.

How is one to take care of the problem of slag formation that accumulates on the furnace walls as affecting heat transfer?

How is one to compare the projected area of a boiler sheet with a bank of staggered tubes? This problem is very complicated; in fact, only an empirical method leads to a reliable result.

Is it possible to compare the heating surface of a large steam generator furnace with a rolling mill furnace?

Some equations call for the so-called flame temperature. How can one determine accurately the flame temperature? The temperature is different at various points in the flame. Is it possible to determine a true average refractory temperature?

Upon examination of equations (1) and (2) one notices other terms which complicate the solution. For example, engineers may disagree as to what constitutes the portion of the flame directed toward the refractory surface.

Notice the complex form of equation (3), which involves such terms as the gas stream temperature, inner surface temperature and surface conductance. The unwieldy nature of equations (3) and (4) are obvious after careful examination.

#### Empirical Solution Favored

From the foregoing discussion it is apparent that the first two methods of analysis lead to general formulas which are not entirely reliable and are very difficult to manipulate. A very practical way to solve problems dealing with the transmission of heat in a combustion chamber is to establish general formulas based on collected experimental data, the formulas are then only applicable to specific cases.

The importance of the problem was summed up by Orrok<sup>4</sup> some years ago in this statement: "But the problem is still with us and a solution must be reached empirically if not rationally, since the increasing demands on boiler surfaces have made water-cooled walls, water screens, radiant heat superheaters, and other devices a practical necessity."

<sup>3</sup> Orrok, G. A., Discussion of "Radiation in Boiler Furnaces" by B. N. Broido, *Trans. Amer. Soc. Mech. Eng.*, 47, 1148 (1925).

#### Ickes Announces Policy Affecting Loans for Municipal Plants

Secretary Ickes has announced a new policy with reference to Public Works loans for municipal power plants. This is to the effect that such loans will be made only when they assure lower rates for electricity to consumers than are offered by the privately owned utility serving the community and where the loan can be amortized within a reasonable period. This announced policy will afford a utility that is threatened with municipal competition to readjust its rates to lowest point consistent with service and a reasonable profit. However, to forestall such an adjustment being made a temporary expedient, Secretary Ickes further announced that the Public Works Administration would cooperate with municipalities to prevent rising rates on indication that proposed municipal plants are not to be built. To this end applications will be held in suspense until the lowered rates filed by the utilities are in effect legally.

\*  $R$  = degrees Rankine =  $F + 460$ .  
<sup>4</sup> Orrok, G. A., *Trans. Amer. Soc. Mech. Eng.*, 47, 1148 (1925).

# The Fulham Power Station

By DAVID BROWNLIE

British Correspondent

This London power station, now in course of erection on the Thames by the Fulham Borough Council, is laid out for an ultimate capacity of 300,000 kw of which 120,000 kw is now being installed. Moderate pressure, high steam temperature, medium size, stoker-fired boilers, air heaters and economizers, high stacks and washing of the stack gases to eliminate sulphur fumes are features of the design.

The station will be completed in 1935.

THE first section of the new Fulham Station, now under construction by the Fulham Borough Council and scheduled for completion late in 1935 will contain six boilers and two 60,000-kw turbine generators. The ultimate plant will have sixteen boilers and five turbine generators of this capacity, aggregating a total of 300,000 kw. This means a layout of three boilers per turbine and one spare. The six boilers will be served by two 300-ft reinforced concrete stacks, 18 ft internal diameter at the top and providing for an exit velocity of the stack gases of about 28 ft per sec. The high concrete or brick stack is in line with present British practice to avoid corrosion from sulphur fumes, incident to a steel stack, and to aid dispersion of the stack gases. Two additional stacks will be added when the boiler plant is ultimately extended to include sixteen boilers.

## Gas Washing to be Employed

As in the case of the Battersea Station, which has attracted wide attention, the flue gases will be washed although details of the gas-washing system are not yet available. It was necessary to adopt gas washing because of public objection to atmospheric pollution by the erection of the station in the heart of London and the burning of coal that runs relatively high in sulphur content.

A moderate working pressure of 625 lb at the superheater outlet and a steam temperature of 850 F was selected. The boilers are of the three-drum Stirling type, each containing 22,680 sq ft of water-heating surface, exclusive of water walls. The drums are of forged construction.

Each boiler is fired by a multiple-retort underfeed stoker eighteen retorts wide, and consuming 14 long

tons of coal per hour at normal load of 260,000 lb of steam per hour. The furnace has Bailey water-cooled walls at the sides and rear with a special water screen at the front.

The superheaters are of the single-pass convection type arranged with primary superheater, de-superheater and secondary superheater, so as to provide temperature control. The design is such that the temperature reaches 850 F at an evaporation of 150,000 lb per hr, above which a portion of the steam is by-passed through the de-superheater and then returned to the secondary superheater. The de-superheater is under thermostatic control. Incidentally, this is the first British station to adopt this system of temperature control.

The economizers are of the gilled-tube, non-steaming type of 14,700 sq ft heating surface, each being fitted with four single-nozzle soot blowers. The tubes are of steel on which are shrunk cast-iron sleeves carrying the gills.

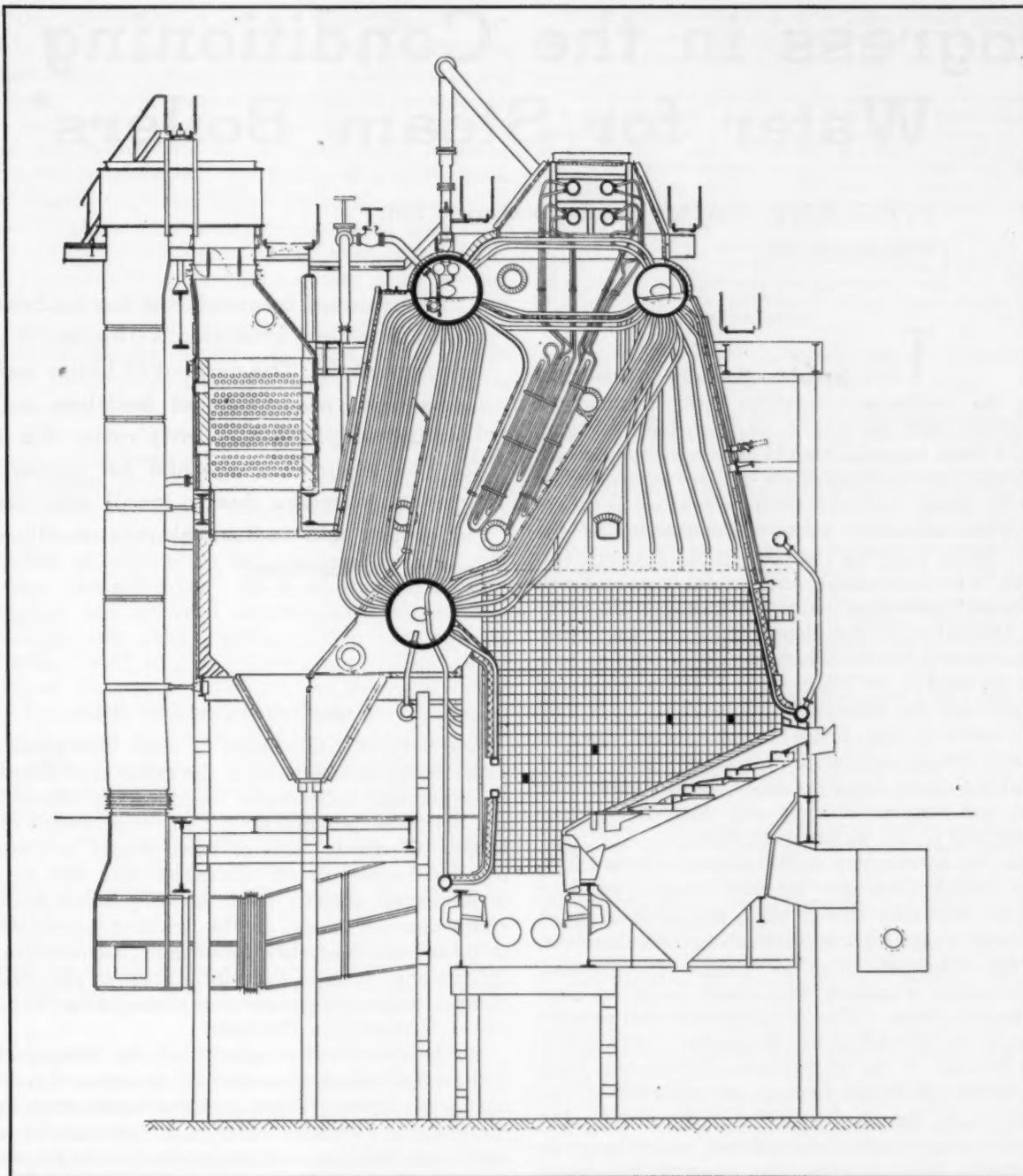
There are two Ljungstrom regenerative type air heaters to each boiler, with a combined heating surface of 34,500 sq ft. These air heaters will reduce the temperature of the combustion gases under normal load from 512 to 240 F and will heat the incoming air for combustion to 400 F.

Ash handling is on the "Hydrojet" principle, the materials after passing through the crusher rolls below the stoker being quenched in firebrick-lined cast-iron hoppers of 20-tons capacity, sufficient for 12 hr running when the coal contains 12 per cent ash. The sluiceway will deliver the quenched ash to storage bunkers from which it can be discharged to barges for dumping at sea. However, a screening plant will also be installed so that part of the screened ash and clinker can be disposed of for building purposes, when the demand warrants such use of the ash.

Inasmuch as the station is located on the River Thames, coal will be delivered by barges for which purpose a coal dock and electrically-operated coal conveying equipment is being installed.

## Five-stage Feedwater Heating

The two turbine-generators are each of the two cylinder impulse type, 60,000 kw maximum continuous rating at 50 cycles and 11,000 volts, running at 1500 rpm, with steam conditions of 600 lb per sq in. and 800 F at the turbine stop valve, and 29 in. vacuum. The most economical load is 48,000 kw. The high-pressure cylinder contains a velocity compounding stage, followed by 21 impulse stages, along with duplex multi-exhaust. These turbines are designed for five-stage feedwater heating, giving a final temperature in the water of 342 F under



Section through boiler unit at Fulham Station

normal running conditions. Boiler feed make-up is supplied by double-effect evaporators, each of 400 tons per day capacity and deaerators will be included.

Each turbine will exhaust to a single-shell, all-welded plate condenser having 54,000 sq ft of surface. These are the largest welded single-shell condensers as yet built in England.

The circulating water is handled by two propeller pumps driven by variable-speed slip-ring motors, each capable of delivering 22,000 gal of water per min from the Thames against a total head of 24 ft when running at a speed of 485 rpm. These pumps are of the Vickers gill design in which the maintenance of high efficiency is not dependent upon small clearances.

There will be a 10,000 kw house turbine-generator of the Brush-Ljungstrom type. This is a double-rotation

condensing machine with 41 radial stages, and, in the same casing, double axial flow exhaust having two reaction stages on each side. Two-stage bleeding is adopted to heat the condensate to 150 F.

The provisional cost of this first section of the station is estimated at the equivalent of \$105 per kw, while the completed station will cost about \$87 per kw. These costs are much higher than is usual in Great Britain, but this is stated to be due to an expensive site, extra standby boilers, but not standby turbines, very high stacks and the chimney gas-washing plant.

Calculations on the basis of a load factor of 50 per cent a heating value in the coal of 10,600 Btu per lb, and cost of the coal as delivered at \$4 per ton, show the total cost per unit generated for this first section will be about 0.5 cent per kilowatt-hour.

# Progress in the Conditioning of Water for Steam Boilers\*

By R. E. HALL, Director Hall Laboratories, Inc.  
Pittsburgh, Pa.

THE desirable alkalinity in the boiler water is the minimum compatible with economic use of phosphate and prevention of corrosion. Higher alkalinities than essential should be avoided, since increase in alkalinity is accelerative of carry-over of boiler water in the steam, and since the maintenance of the sodium sulphate-alkalinity ratios, recommended in the A.S.M.E. Boiler Code for the prevention of caustic embrittlement is far more simply and certainly attained with the minimum rather than higher alkalinities in the boiler water. Alkalinity is the denominator of the ratio. Therefore, when it is a minimum, the quantity of sodium sulphate required in the boiler water is also a minimum. This means that the chances of trouble from carry-over of boiler water in the steam are minimized, because with lower concentrations of dissolved solids in the boiler water there is lesser tendency for any carry-over to occur, and because, if carry-over does occur, there is less material in the water to do damage.

Because the tendency of boiler waters is toward high alkalinity rather than low in most cases, control of boiler water alkalinity should begin with proper choice of feedwater treatment. Additional to this, however, it has been necessary to devise means of controlling the boiler water alkalinity that could safely be used in all types of plants. The use of acid for this purpose is a thing to be avoided if at all possible. This end is attained by use of the molecularly dehydrated phosphates. While they are neutral as dissolved in the feedwater, when they arrive in the boiler water they are transformed gradually into ordinary orthophosphate form whereby they provide the essential phosphate radical to combine with calcium and prevent scale formation, and at the same time, produce hydrogen ion which neutralizes the alkalinity in the boiler water. Thus it becomes possible to reduce or control the boiler-water alkalinity as desired, and without danger of corrosion of feed lines or boiler.

We would emphasize the tremendous importance of the exact control, and maintenance at a minimum, of the boiler-water alkalinity. Time and again, in the Pittsburgh area, where the waters are sulphate in character, we have found in the boiler waters a content of alkalinity introduced by treatment of the feedwater well nigh equal to or even greater than all other solubles resulting from those in the natural water. There is no excuse for these conditions, since cleanliness of boilers and their freedom from corrosion are as readily and as economically attainable at desirable low alkalinites as at those which are so excessively high.

Preliminary treatment of the feedwater is assumed and attention is directed to the boiler water. The control of boiler water alkalinity, prevention of feed-line scale, sodium sulphate-alkalinity ratio, the use of the Magnaflux method for exploring cracks, corrosion due to small quantities of oxygen and sodium-aluminum-silicate scales are discussed.

## *Prevention of Feed Line Scale*

Necessity of maintenance of exact conditions in the boiler water brought with it the problem of distributing the essential boiler-water conditioning chemicals to the boilers in proportion to their requirement of feedwater. Obviously, this is most simply accomplished by introduction of the chemicals into the feedwater in proportion thereto, following its primary treatment. Unfortunately, many of the treating chemicals such as tri-sodium phosphate cause much trouble if used in this manner because they form scale in the feed lines and pre-boiler equipment, thus endangering the supplying of feedwater to the boiler.

In the cold-water chemistry of the molecularly dehydrated phosphates, an effective answer to this problem has been found. When sodium hexametaphosphate, for instance, is added in requisite amount to a hard water, the calcium and magnesium are sequestered so firmly in the complex metaphosphate radical that even the most searching reagents fail to locate them in the water. The water is absolutely soft, and moreover, in proportion to the excess of the metaphosphate present, actually exercises dissolving power on any deposits such as calcium carbonate or calcium phosphate with which they may come in contact. Inasmuch as the amount of phosphate required to sequester the calcium in this manner is greater than that required to precipitate it as tricalcic phosphate in the boiler water, the molecularly dehydrated phosphate is introduced intermittently into the feedwater so that during each period, when it is being added, its excess in the feedwater is sufficient to sequester thoroughly the calcium and magnesium and provide solvent action on any deposits that have been laid down in the intervals between the intermittent feeding. Thus it becomes possible to secure the advantages inherent in supplying the requisite boiler-water phosphate to the feedwater without incurring the disadvantages of feed line scale.

\* From a paper delivered before the Engineers Society of Western Penna.

For the prevention of caustic embrittlement, the A.S.M.E. Boiler Code recommends the maintenance of certain ratios of sodium sulphate to alkalinity in the boiler water. The protection thus gained is presumably due to the formation over the metal of impermeable scale of sodium sulphate as the boiler water becomes concentrated in seams or other points to a degree such that its caustic might be deleterious to the metal.

Since the ratios at present recommended have been reached without definite data on the solubility and the various crystal phases of sodium sulphate, it has become advisable to investigate these both in pure solution and in the presence of such concentrations of caustic, soda ash, chloride, phosphate, etc., as might be present in the boiler water, or be developed by its evaporation in varying degree. This work is proceeding at the United States Bureau of Mines Experiment Station at New Brunswick, as a cooperative project of the A.S.M.E. and the Bureau, and is supported by the contributions of some sixty companies which recognize its timely value.

Proposals of substitutes for the sulphate-alkalinity ratio have been numerous. Of these, the maintenance of phosphate in very small amount in the boiler water has received the widest publicity. On the basis of experimental work at the University of Illinois, Parr and Straub have taken patents on this procedure.<sup>1</sup> At the University of Michigan, White and Schneidewind have found intercrystalline cracking in metal in contact with phosphate.<sup>2</sup> Dr. A. Splittergerber, perhaps the best known authority on water conditioning in Germany, emphasizing the merits of phosphate for the removal of scale and its prevention, but refusing to recognize in it any ability to bear the added burden of preventing embrittlement also, makes the following statement<sup>3</sup>:

"As a substitute, or as a supplementary material for sulphate in the prevention of embrittlement in riveted boilers, phosphate cannot be made use of since it is apparently conducive to the formation of caustic embrittlement in the same manner as caustic soda."

With suitable control of the boiler water alkalinity, there is no trouble in maintaining in the boiler water the sulphate-alkalinity ratios specified in the Code. It is recommended that these ratios be maintained until such time as the protective value of any other means of preventing embrittlement cracking have been indubitably proved.

#### *Use of Magnaflux Method in Exploring for Cracks*

Many wearisome hours have been spent in boiler drums and heavy strain put on eyes despite the assistance of microscopes and the best cleansing possible, in the attempt to estimate to what extent cracking of the metal may have damaged the fitness of the boiler for use.

Last year, W. E. Casey, Superintendent of Power of the Denver Tramway Corporation, had to examine a boiler which had been in service for a score of years, and by use of the Magnaflux method obtained such outstanding results and with such ease that the method deserves use wherever similar problems are encountered. I will first briefly describe the method by quotations from the Magnaflux folder, and then quote Mr. Casey.

<sup>1</sup> U. S. Patent 1,910,403, May 23, 1933.

<sup>2</sup> Trans. Am. Soc. Mech. Eng. (1930).

<sup>3</sup> Vom Wasser, Vol. 6, p. 209 (1932).

"Magnaflux powder is a light gray colored powder of high magnetic permeability used for indicating the size, position and extent of cracks, seams or other defects in the above mentioned materials.

"The part to be inspected is first magnetized which may be done in one or all of some half dozen ways. It is then either rolled in a box of Magnaflux powder, or the powder is dusted on by means of a container with perforated openings. When the part is tapped or shaken the powder all falls off unless there is a flaw of the type sought after. In this case the defect will be found outlined with a ridge of gray powder usually plainly marked and visible at a distance of some feet.

"The Magnaflux method will not test quality; it will not locate pipe or porous spots in round bars or billets, and will not locate blow holes or inclusions in castings unless very near the surface. It is best adapted to the type of defect whose length and depth are great compared to its width."

Passing now to Mr. Casey's account of his use of this method and the results obtained, he says:

"The problem which we had was an examination of the front seam of the mud drum on a bent-tube 705-hp Stirling boiler. The early part of this investigation consisted of removing several rivets along the calking edge of the butt strap and exploring the rivet holes with magnifying glass and a pyroscope that magnified approximately 20 diameters. This is the method generally used by insurance inspectors and taxes the visual and physical powers of the inspectors on a job of this nature in determining which are cracks and which are tool marks and scratches and then if any question arises a recheck is necessary.

"We heard of another method of exploring very small cracks in steel developed by Dr. A. V. de Forest. This is a magnetic method and proved rather successful on our job after some experimenting. We tried using a hand magnet at first and the results secured by this method were indifferent. The outside butt strap was removed and we were rather surprised to find that the condition of the plate was not as serious as it was first thought to be after inspecting the inside of the rivet holes with the magnifying glass. The hand magnet was placed inside the drum but the inside butt strap acted as a magnetic shunt between the two plates and on this account it was impossible to secure a sufficient amount of magnetic flux through the plate. The magnet was then placed on the outside of the drum and an attempt was made to examine the hole lying within the magnetic field but the leakage of the flux from all parts of the plate and a tendency of the Magnaflux to adhere to all parts of the surface of the plate in the magnetic path, decreased the magnet strength and did not develop the cracks very distinctly.

"We finally decided to produce a complete closed magnetic circuit through the boiler plate and the inside butt strap in a circumferential direction by means of winding through 4 rivet holes, near the extreme ends of the drum, 20 turns of No. 6 wire, using an excitation current of approximately 100 amp. Very little surface leakage of the flux took place from the plates, although the flux density in the boiler plate was evidently quite high.

"The Magnaflux was put in small cloth bags and dusted on the plate through the cloth and when the plate was magnetized as outlined above, the cracks developed with remarkable ease and certainty, giving a visual picture of all the cracks that existed in the drum sheet.

"It was then thought that by numbering the rivet holes and photographing this section of the drum we would have a record of the existing condition of the drum sheet. After this was done the length of the cracks was measured and recorded on a set of photographs which can be checked at any future time to see if the cracks are increasing in length.

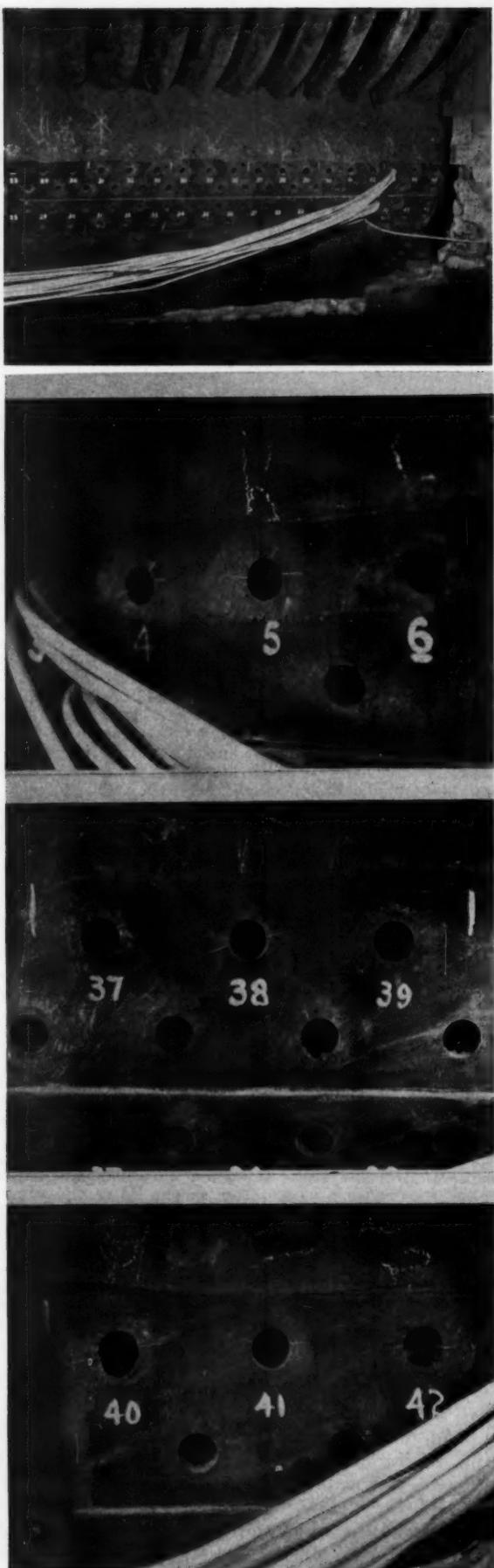
"By using the magnetic method many more cracks were found than by the use of the magnifying glass. This method is simple and requires but very little experience to apply. The photographing perhaps required the most experience. We used two photo flood lamps arranged in ordinary office desk reflectors to furnish the necessary light."

The illustrations show the result of working in this way.

An examination in this manner of every boiler before riveting would not be onerous, and would definitely detect any incipient cracking before it went into service.

#### *An Aggressive Attack on Corrosion Due to Small Quantities of Oxygen*

As the surfaces of boilers have been kept freer of scale, it has become important to provide more effectively than in the past against the contingency of corrosion.



Photographs of boiler drums inspected by the  
Magnaflux method

An example will illustrate. In the plant which we will consider, the make-up water is lime-soda treated and therefore alkaline, and the condensate is of excellent quality. The feedwater passes through deaerating equipment of standard make and then through integral economizers to the boilers. The feedwater tested at regular and rather frequent intervals by the regular Winkler test, showed "zero oxygen" day after day, and therefore undoubtedly contained not more than 0.03 ml per liter of oxygen. Every care was taken in performing the Winkler test to follow well-recommended technique, and likewise the best recommendations for the chemicals and starch used in the test. Despite the apparently *zero oxygen* condition, corrosion of the integral economizers persisted. Observation of the temperature chart on the deaerator showed irregularities at infrequent intervals, and this condition was corrected by bleeding live steam under suitable control to the deaerator. And yet, despite the certainty of correct alkalinity conditions in the feedwater and zero-oxygen by the Winkler test, corrosion of the integral economizers persisted, in not marked measure to be sure, nevertheless in definitely active fashion.

How can corrosion occur under those conditions to an extent that makes necessary its prevention? To understand its mechanism, it is necessary to review the operations which have given the zero oxygen feedwater, and the conditions in the integral economizer itself.

All deaerating equipment operates on the basis of the partial-pressure law of Henry and Dalton. This law states that the amount of oxygen dissolved in water in equilibrium with a vapor phase, is at all times proportional to the partial pressure of oxygen in the vapor phase. Thus, water in contact with air at atmospheric pressure dissolves a certain amount of oxygen at any given temperature. If the pressure of the air is halved, the amount of oxygen dissolved in the water at equilibrium is also halved; if the pressure of the air is doubled, the amount of oxygen dissolved in the water is doubled. In deaerating equipment, the vapors which are vented continually carry away the oxygen evolved from the water in the equipment. If the vapors in contact with the water, as for instance the steam in the deaerating heater, are totally free of oxygen, then if sufficient time is given for equilibrium to be attained in the heater, the water effluent therefrom should be absolutely free of oxygen. In general, however, the vapor in contact with the water is not totally free of oxygen. Likewise, in general, sufficient time cannot be given in the heater for equilibrium to be obtained, since, to attain this end, the apparatus would have to be enormously larger than is customary in order that every molecule of oxygen might have time to travel from the interior to the surface of the little droplet in which it is contained and then embark in the gaseous phase. Nevertheless, the water from these heaters is frequently termed zero-oxygen content. The reason for this is the fact that while the Winkler test is thoroughly sound for determining the amount of oxygen present above the minimum at which the test fails, it is not of value below this minimum which really represents, therefore, what is commonly called zero oxygen water.

The minimum of oxygen in the water at which the Winkler test is reliable is perhaps 0.03 ml per liter.

By special precautions with the chemicals that are used, and special technique in taking of samples, it is perhaps possible to extend this minimum to 0.02 or 0.01 ml per liter.<sup>4</sup> The precautionary measures necessary to obtain any accuracy for the minimum 0.01 ml per liter, however, are so numerous as to preclude the possibility of their adoption in routine work, so that for the ordinary testing in the plant if a minimum of 0.03 ml per liter is measured with certainty, it should be satisfactory. The 810 million billion molecules of oxygen per liter which is the number corresponding to 0.03 ml per liter, are evidence that the water is not of zero oxygen quality in reality.

A piece of iron in contact with water containing 810 million billion molecules of oxygen, will proceed to combine chemically with a great proportion of these molecules with formation of iron oxide and with the retirement of the oxygen from its presence in solution as such. If the water is sufficiently alkaline to repress any dissolution of iron, then this fixation of oxygen will not occur. On the other hand, if the iron is suspended above this zero oxygen water in an air-free atmosphere, and even though the water is alkaline, it will gradually combine with the oxygen because in accordance with the partial pressure law of Henry and Dalton some of the dissolved oxygen will be furnished to the space in which the iron is suspended, and the iron will combine with this oxygen, since it is in a moist atmosphere devoid of alkali.

Let us carry that picture into the integral economizer. Let us suppose that we have small chance areas of the metal surface covered with a gaseous film perhaps no more than 0.001 in. in thickness. To the oxygen molecule 0.001 in. represents wide-open spaces. Films of this sort are liable to occur and to remain, as for example, at the periphery of joining of tube and boiler sheet where the tube is rolled in. The boiler water may be alkaline, but the area under this little film is not alkaline. Thus, iron in contact with the film combines with or fixes oxygen coming to the film and reduces its partial pressure to exceedingly low value. In the boiler water passing by, however, which has been deaerated to the extent of 810 million billion of molecules per liter, there is a steady supply of oxygen molecules desirous of establishing their partial pressure relationship in this gaseous film on the basis of the law of Henry and Dalton. They do so, and thereby supply oxygen to this small space. Immediately, however, the iron combines with it, and the water then supplies more oxygen. So the process goes on, the trifling corrosion of the moment is integrated into the serious corrosion of hundreds of hours, and a condition develops which must not exist in the boiler.

Prevention consists in providing in the boiler water a condition such that every molecule of oxygen which enters will be chemically fixed before it has time to make contact with the metal at any of the small vapor spaces that may by chance exist. With the concentration of oxygen thus lowered to a similar or lower amount than corresponds to what would be in equilibrium with the iron, there is no longer any tendency for molecules thereof to escape into these small spaces and no corrosion can occur.

<sup>4</sup> Since this paper was written, methods have been proposed by Yoder and Dresher, COMBUSTION, Vol. 5, No. 4, pp. 18-22, and by Schwartz and Gurney, A.S.T.M. preprint, 1934, which are a notable improvement on the regular Winkler method.

Many materials might be used thus to chemically fix oxygen. Tannic acid bodies such as Cutch or Quebracho probably combine with a small amount of oxygen, but the number of pounds required per pound of oxygen renders excessive their cost for this purpose, and they also highly discolor the boiler water. Finely divided iron powder might be used, or ferrous sulphate or hydroxide supplied to the alkaline feedwater would suffice for the purpose. In the boiler, however, the iron salts produce a heavy sludge of ferric hydroxide and are therefore undesirable. Also, none of these materials can be readily tested to learn if the necessary excess is present in the boiler water. On the other hand, sodium sulphite readily combines with oxygen to form sodium sulphate, and with sufficient totality so that the boiler water can furnish no oxygen to the boiler metal. Eight pounds of anhydrous sodium sulphite will combine with one pound of oxygen. The product formed, sodium sulphate, is useful in building up the sodium sulphate of the boiler water. No objectionable discoloration or sludge is produced in the reaction. Finally, it is easy to test the boiler water for the sulphite therein so that with its use it becomes possible to maintain in the boiler water that concentration of sulphite molecules which gives assurance at all times that any entering oxygen molecule will be fixed by the sulphite so that it cannot combine with the iron. In other words, the maintenance of the sulphite constitutes an aggressive attack on corrosion where the quantity of oxygen has been a minimum undetectable by the Winkler test.

It is not advisable to consider chemical fixation of oxygen in the water as a substitute for deaerating equipment, but it should be looked upon as a secondary line of defense following the deaerating equipment.

The failure of the Winkler test at a minimum that still represents some 810 million billion molecules of oxygen in the water, emphasizes the futility of attempting their control by testing for them with the Winkler test in any form. An analogous operation would be to attempt to control the boiler water by testing for the calcium that it contains. These tests for oxygen and calcium are good enough down to the minimum at which they fail, but if the minimum does damage and must be reckoned with, then the thing to do is to change the line of attack, and instead of vainly testing for the disappearing material, proceed with maintenance in the water in suitable measurable quantity the substance which combines with and removes the minimum. This aggressive attack deals with quantities of sufficient magnitude to respond readily and with certainty to simple routine testing.

Thus, just as phosphate maintained in the boiler water in readily measurable quantities searches out and combines with the calcium atoms so that they cannot combine otherwise to form scale, likewise the maintenance of sulphite in as readily measurable quantities provides a similar impregnable final line of defense against any molecules of oxygen that are not removed by the deaerating equipment.

#### Sodium-Aluminum-Silicate Boiler Scales

In Table I are analyses of a number of samples of ordinary hard, adherent silicate scale which formed at different operating pressures as noted; in Table II are

TABLE I ORDINARY SILICATE SCALES

Type of boiler	Analyses in Per Cent					
	1 B.&W. long drum	2 Stir- ring tubes	3 Cross drum	4 Cross drum	5 Two vertical drum	6 Stir- ring tubes
Operating pressure, lb	400	375	325	275	210	150
Location of scale	Lower tubes	Tubes	Tubes	Tubes	Tubes	Tubes
Composition of scale						
Sulphur trioxide ( $\text{SO}_3$ )	1.2	0.5	2.6	0.5	0.3	1.2
Carbon dioxide ( $\text{CO}_2$ )	2.4	Trace	...	2.0	11.1	1.1
Phosphorus pentoxide ( $\text{P}_2\text{O}_5$ )	16.0	6.0	6.5	...	9.9	...
Silica ( $\text{SiO}_2$ )	22.5	39.9	37.0	55.8	34.2	44.8
Ferric oxide ( $\text{Fe}_2\text{O}_3$ )	{ 10.3	{ 4.6	{ 12.4	{ 8.3	{ 2.8	{ 11.0
Aluminum oxide ( $\text{Al}_2\text{O}_3$ )	33.6	36.2	34.9	25.2	42.5	24.4
Calcium oxide ( $\text{CaO}$ )	5.8	4.2	2.7	3.1	2.8	2.1
Magnesium oxide ( $\text{MgO}$ )	8.0	4.9	3.9	7.3	6.6	5.5
Ignition loss						
Total	99.8	101.1	100.0	102.2	100.3	100.0

analyses of a different type of hard, adherent silicate scale, characterized by its high percentage of alumina ( $\text{Al}_2\text{O}_3$ ) and of sodium oxide ( $\text{Na}_2\text{O}$ ). In ordinary silicate scale there is little or no sodium oxide present, and the main constituent is calcium silicate, as indicated by the large percentages of both calcium oxide and silica in the samples of Table I. In the sodium-aluminum-silicate scales of Table II, the percentage of silica is high, but the content of calcium oxide as well as magnesium oxide is relatively low. Sodium-aluminosilicate [ $\text{NaAl}(\text{SiO}_3)_2$  or similar formula] forms the main constituent. Increase in amount of sodium oxide as the pressure of operation increases is notable. It illustrates a greater tendency for the sodium-aluminosilicate scales to form at the higher rather than the lower pressures. Formation of the sodium-aluminosilicate scales is not, however, universal at the higher operating pressures, and apparently is a function of special conditions in the boiler water, since in the examples illustrated in Table I only the ordinary calcium-silicate scales have formed at the higher as well as the lower pressures.

The conclusion seems justified that one special condition which may result in formation of the sodium-aluminosilicate scale is constantly available alumina in the boiler water. A second special condition is a relation of rate of steam generation to circulation in localized hardest worked sections of the boiler such that practically complete evaporation of boiler water intermittently occurs, with equally periodic drying and baking of deposits on the surfaces of these sections. In the absence of a steady supply of alumina, maintenance of requisite phosphate equilibria in the boiler water completely prevents formation of silicate scales whatever the operating pressure. The alkalinity requisite for this prevention is not high, although higher than that required where silica is absent from the water. The higher alkalinity is effective in giving minimum solubility to calcium phosphate, thus the boiler water is kept practically entirely free of calcium, and hence calcium-silicate scale does not form. Under these conditions of alkalinity when magnesium silicate forms, it is not adherent but flocculent in character. In case of intermittent complete evaporation and drying on some surfaces, because of local excessive ratings, periodic contact with the alkaline phosphate-containing water causes redissolution of calcium silicate or sulphate and its precipitation as calcium phosphate sludge.

Phosphate cannot deter formation of sodium-aluminosilicate scales, because of the amphoteric characteristics of aluminum, nor can it effect their redissolution, once they are formed. Aluminum phosphate is quite insoluble in neutral water, but dissolves in

alkaline water with formation of sodium phosphate and sodium aluminate. Since it is essential that the boiler water be alkaline, it is needless to expect that phosphate will remove the aluminum as aluminum phosphate therefrom. Thus alumina, once present in the boiler water, cannot be prevented from reacting with the silica therein to form the hard, adherent sodium-aluminum-silicate scale; and once the deposit is formed, the phosphate in the boiler water cannot effect its dissolution. According to our observations, conditions most favorable to its formation are those of localized excessive rate of evaporation and presumably intermittent complete evaporation of portions of the boiler water.

For preventing the formation of this type of scale one step is mechanical and consists in eliminating localized excessive ratings, and intermittently occurring complete, or well-nigh complete, evaporation of portions of the boiler water. Other steps, chemical in nature, may be classified thus: (1) Removal of silica from the water; (2) Removal of alumina from the water; (3) Excessive碱alities in the boiler water. These will be discussed in order.

Removal of silica by use of alumina has been proposed by Christman, Holmes and Thompson.<sup>5</sup> Any removal effected in the softener by the coagulative properties of alumina is regarded by these authors as aided by having alumina maintained in the boiler water for the purpose of precipitating silica in the form of calcium- or magnesium-aluminum-silicate in flocculent form. Stumpfer more recently<sup>6</sup> considers the use of alumina of value in removal of silica, from the standpoint of its coagulative effect, but recommends that in its use it is important to control the alkalinity eventually developed in the water, a recommendation which if followed prevents its passage through the filter of the softener.

There can be no objection to use of alumina for coagulative purposes and for any removal of silica it may effect in the softener, because its drag-net effect in clarifying the water of finely divided or even colloidal substances is excellent. Use of more of the alumina than is necessary for this effect is vain. This effect is particularly well illustrated by its use in the cold-process lime-soda softener. We believe that the pH value of the water in the softener should be so controlled that the least possible minimum of the alumina remains in the water passing through the filter.

What happens if the alumina goes to the boiler water?

TABLE II SODIUM-ALUMINUM-SILICATE SCALES

Type of boiler	Analyses in Per Cent					
	1 Bent tube steam generator	2 Cross drum	3 Cross drum	4 Cross drum	5 Connelly bent tube	6 Stir- ring tube
Operating pressure, lb	1650	650	450	400	220	175
Location of scale	Water wall tubes	Water wall tubes	Water wall tubes	Bottom tubes	Front row tubes	Front bank of tubes
Composition of scale						
Sulphur trioxide ( $\text{SO}_3$ )	3.9	0.4	0.1	1.0	1.2	1.7
Carbon dioxide ( $\text{CO}_2$ )	Trace	...	...	Trace	Trace	...
Phosphorus pentoxide ( $\text{P}_2\text{O}_5$ )	13.8	16.7	0.5	6.4	5.0	Trace
Silica ( $\text{SiO}_2$ )	21.4	27.6	44.0	43.5	39.3	34.6
Ferric oxide ( $\text{Fe}_2\text{O}_3$ )	9.1	5.2	13.5	3.1	11.8	Trace
Aluminum oxide ( $\text{Al}_2\text{O}_3$ )	19.4	14.0	25.0	19.1	16.2	7.5
Calcium oxide ( $\text{CaO}$ )	6.3	16.5	0.8	9.1	9.1	35.5
Magnesium oxide ( $\text{MgO}$ )	3.5	3.6	0.6	3.4	0.9	2.5
Sodium oxide ( $\text{Na}_2\text{O}$ )	17.8	10.8	9.8	8.1	7.2	1.6
Ignition loss	6.8	6.2	7.3	7.4	7.3	14.0
Total	102.0	101.0	101.6	101.1	98.0*	103.4

\* Contains 1 per cent of chloride (Cl).

<sup>5</sup> Ind. Eng. Chem., Vol. 23, pp. 837-46, 849-50 (1931).

<sup>6</sup> Wärme, Vol. 55, pp. 272-8 (1932).

As noted by Christman, Holmes and Thompson, calcium or magnesium aluminum silicates may form, and be endowed with the base exchange properties characterizing zeolitic chemicals as used in the zeolite softener. This is likely since any examination of the patent literature on the synthetic zeolite chemicals acquaints one with the fact that the synthetic aluminum alkali-metal silicates are readily formed by appropriately bringing together alumina and alkali-metal silicate in slightly acid, neutral or alkaline solution.<sup>7</sup> The base exchange property, however, defeats any advantages of thus precipitating the silica, since, as the sodium concentration in the boiler water increases, sodium will replace any calcium or magnesium in the calcium or magnesium aluminum silicates, thus forming the sodium aluminum silicate which is definitely established as an injurious scale. In our own experience it has been found that any attempt to effect precipitation of the silica in the boiler water in this manner leads to difficulties. Furthermore, since silica is usually present in appreciable amount, any method for its precipitation will necessarily involve added expense.

At times it is advantageous to make use of the excellent characteristics of alumina in flocculating impurities out of the water, such as oil in condensate, or colloidal calcium carbonate in the cold-process softener. In such use, however, it is possible to bring the water through the filter after such coagulation practically as free of alumina as it is in its natural state by strict control of pH values during the process of coagulation and filtration. It may eventually be possible to use the ferric salts with their excellent flocculating characteristics<sup>8</sup> for this type of coagulation, and thus avoid this close control, since iron is not amphoteric, and thus permits much greater leeway of pH value during the coagulative processes, without danger of passage through the filter. In the meantime, however, use of alumina for flocculating purposes with strict control over pH value is giving excellent results, and we have found it possible to maintain the freedom from alumina which is necessary in the boiler water in order to circumvent formation of sodium-aluminum-silicate scale in sufficient measure for practical purposes.

In the prevention of sodium-aluminum-silicate scale, however, where there is some aluminum steadily arriving in the boiler water, it is essential that the alkalinity of the boiler water be maintained much higher than is necessary for any other purpose—much higher than is necessary for prevention of the common silicate scales. Presumably this high alkalinity attacks the sodium aluminum silicate with formation of sodium aluminate, in which the aluminum is so tightly sequestered in the aluminate radical that it will no longer remain in combination in the sodium aluminum silicate. If the entering aluminum is considerable, excessive碱alities must be maintained. If the entering aluminum is held at its minimum, then undesirably high but nevertheless possible alkalities must be maintained.

The best procedure for elimination of the sodium-aluminum-silicate scales, therefore, is, we believe, to prevent in so far as possible localized excessive rates of evaporation; also, entrance of alumina into the

boiler water; and then to establish in the boiler water the alkalinity requisite to prevent the minimum that enters despite all precautions from forming into this undesirable type of scale.

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### Roger W. Andrews Becomes Western Division Manager of Combustion Engineering Company, Inc.



Under the direction of H. S. Colby, General Sales Manager, a Western Division of the sales organization of Combustion Engineering Company has been formed, comprising the Chicago, Detroit, Indianapolis, St. Louis, Kansas City, Houston, Tulsa, Minneapolis and Denver offices. Roger W. Andrews, until lately Assistant to the President of the Blaw-Knox Company will be

in charge of this division as Western Manager.

Mr. Andrews' connection with the steam power field dates back to 1910 when he joined the Northern Equipment Company, later becoming Sales Engineer, Service Engineer, Chief Engineer, Secretary and General Sales Manager of that company. In 1914 he formed the R. W. Andrews Company of Chicago, handling power plant equipment, and a year later joined with Grant D. Bradshaw, then Steam Engineer of the Cambria Steel Company, to form the Andrews-Bradshaw with headquarters in Pittsburgh.

In the early twenties the Andrews-Bradshaw Company developed, in connection with the Tracy Engineering Company, certain specialized boiler room equipment and took over the engineering and sales for the entire country. In 1928 the Andrews-Bradshaw Company merged with the Blaw-Knox Company of Pittsburgh as a division of the latter and Mr. Andrews became manager of that division. He was later made Assistant to the President in which capacity he spent considerable time in Europe, including Russia, directing the activities of the branch offices and manufacturing plants in England, France, Germany and Italy. He resigned on September first of this year to join Combustion Engineering Company.

Aside from this experience in the power plant field Mr. Andrews helped to organize and direct the Air Service at Washington during the early period of the World War. He was later commissioned an officer and saw much active duty at the headquarters of the Air Service in France.

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A. L. Baker, formerly mechanical engineer with Sargent & Lundy, Chicago is now with M. W. Kellogg Co., New York.

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H. T. Heald has recently been made Dean of Armour Institute of Technology, Chicago.

<sup>7</sup> For instance, U. S. Patent 1,895,121.  
<sup>8</sup> See article by Barthow, Black and Sansbury, *Ind. Eng. Chem.*, Vol. 25, pp. 898-903 (1933).

# A.S.M.E. Annual Meeting Program

## Steam Power and Fuel Papers

The technical program for the 1934 Annual Meeting of the American Society of Mechanical Engineers, to be held at the Engineering Societies Building, New York, December 3 to 6, includes ninety-five papers and progress reports in addition to committee conferences and special lectures. Those papers which should be of greatest interest to steam power engineers are listed as follows:

### Tuesday, 9:30 a.m.

*Air Flow in Fan Discharge Ducts* by LIONEL S. MARKS, Mem. A.S.M.E., Professor of Mechanical Engineering, Harvard University, Cambridge, Mass.

*Progress Report on Fan Research at Lehigh University* by W. E. SOMERS, Jun. A.S.M.E., Lehigh University, Bethlehem, Pa.

*The Intake Orifice and a Proposed Method for Testing Exhaust Fans* by N. C. EBAUGH, Mem. A.S.M.E., and R. WHITFIELD, Georgia School of Technology, Atlanta, Ga.

*Effects of Side Leakage in 120-Degree Centrally Supported Journal Bearings* by SIDNEY J. NEEDS, Mem. A.S.M.E., Kingsbury Machinery Works, Inc., Philadelphia, Pa.

*Performance of Large Journal Bearings* by R. BEAUDRY and L. M. TICHVINSKY, Research Laboratory, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

### Tuesday, 2:00 p.m.

*The Fatigue of Shafts at Fitted Members* by R. E. PETERSON, Assoc.-Mem. A.S.M.E., and A. M. WAHL, Assoc.-Mem. A.S.M.E., East Pittsburgh, Pa.

*Strength and Design of Covers, and Flanges for Vessel Openings* by T. MCLEAN JASPER, Mem. A.S.M.E., H. GREGGESSON, and A. M. ZOELLNER, A. O. Smith Corporation, Milwaukee, Wis.

*Discussion of the Status of the Heat Transfer Between Liquid and Gas in Contact* by A. WEISSELBERG, Jun. A.S.M.E., Consulting Engineer, Jersey City, N. J.

*Investigation of Heat-Transfer Rates on External Surface of Baffled Banks* by R. A. BOWMAN, Jun. A.S.M.E., Westinghouse Electric & Manufacturing Co., Philadelphia, Pa.

### Wednesday, 9:30 a.m.

*Flow Distribution in Forced-Circulation Once-Through Steam Generators* by H. L. SOLBERG, Mem. A.S.M.E., G. A. HAWKINS, Jun. A.S.M.E., and A. A. POTTER, Past-President, A.S.M.E., Purdue University, Lafayette, Indiana

*Influence of Bends or Obstructions at the Fan Discharge Outlet on the Performance of Centrifugal Fans* by L. S. MARKS, Mem. A.S.M.E., J. H. RAUB, Jun. A.S.M.E., and H. R. PRATT, Harvard University, Cambridge, Mass.

*Manufacture of Large Seamless-Steel Tubes by the Tschulenk Forge-Rolling Process* by ARTHUR J. HERSCHEMANN, Mem. A.S.M.E., U.S.A. Agent for Vitkovice Steel Works of C.S.R., New York, N.Y., and L. TSCHULENK, Czechoslovakia

### Wednesday, 2:00 p.m.

*Pulverized-Fuel-Burning Experience at Buzzard Point Plant* by H. G. THIELSCHER, Mem. A.S.M.E., Mechanical Engineer, Potomac Electric Power Company, Washington, D. C.

*The Economics of Preheated Air for Stokers* by R. E. DILLON, Mem. A.S.M.E., Superintendent, Generating Department and M. D. ENGLE, Mem. A.S.M.E., Assistant to Superintendent, Stationary Engineering Department, The Edison Electric Illuminating Co., Boston, Mass.

*The Relative Grindability of Coal* by HAROLD J. SLOMAN and ARTHUR C. BARNHART, Carnegie Institute of Technology, Pittsburgh, Pa.

*Reports on Steam Table Research Work*

*Report of International Steam Table Conference*

### Thursday, 9:30 a.m.

*High-Pressure-Steam and Binary Cycles as a Means of Improving Power-Station Efficiency* by GUSTAF A. GAPPERT, Assoc.-Mem. A.S.M.E., Assistant Professor of Heat Power Engineering, Worcester Polytechnic Institute, Worcester, Mass.

*Fluid-Meter Nozzles* by B. O. BUCKLAND, Jun. A.S.M.E., Turbine Engineering Department, General Electric Company, Schenectady, N. Y.

*Progress Report on Research Work on Dissolved Oxygen* by C. H. FELLOWES, Detroit Edison Company, Detroit, Michigan, Chairman, Subcommittee on Standardization of Water Analysis.

*Navy's Experience With the New Boiler Compound* by R. C. ADAMS, Jr., U. S. Naval Experimental Station, Annapolis, Md.

### Thursday, 2:00 p.m.

*The Test Performance of Hudson Avenue's Most Recent Steam-Generating Units* by P. H. HARDIE, Assoc.-Mem. A.S.M.E., and W. S. COOPER, Assoc.-Mem. A.S.M.E., Research Bureau, Brooklyn Edison Co., Brooklyn, N. Y.

*Ten Years of Stoker Development at Hudson Avenue* by J. M. DRISCOLL, Jun. A.S.M.E., and W. H. SPERR, respectively, Plant Equipment Engineer, and Assistant Plant Equipment Engineer, Mechanical Engineering Department, Brooklyn Edison Co., Brooklyn, N. Y.

*Coal Charges for Banking, Lighting and Burning Out Boiler Units* by GEORGE C. EATON, Head, Mechanical Technical Generating Department, Edison Electric Illuminating Co., Boston, Mass.

*Progress in Power* (Auspices of Power, Oil and Gas Power, Fuels and Hydraulic Divisions)

*A Critical Survey of Published Information Relating to the Embrittlement of Boiler Steel* by EVERETT P. PARTRIDGE and W. C. SCHROEDER, Non-Metallic Minerals Expt. Station, Bureau of Mines, New Brunswick, N. J.

*The Solubility of Sodium Sulphate in Boiler-Water Salines as Related to the Prevention of Embrittlement*—Progress Report No. 3

*The Effect of Solution Composition on the Failure of Highly Stressed Boiler Steel*—Progress Report No. 1

Both Reports by W. C. SCHROEDER and E. P. PARTRIDGE.

There will be the usual business meeting of the Society on Monday afternoon, the Thurston Lecture on Tuesday afternoon, the President's address and reception on Tuesday evening and the annual dinner at the Hotel Astor on Wednesday evening. The Towne Lecture will be delivered by Dexter S. Kimball on Thursday evening following an economies session at Stevens Institute, Hoboken, which will discuss problems of recovery in the durable goods industries. A special feature on this year's program is the Calvin W. Rice Lecture scheduled for Wednesday afternoon which will deal with Doctor Rice's contribution to International Friendliness. An interesting program of excursions has been arranged.

# STEAM ENGINEERING ABROAD

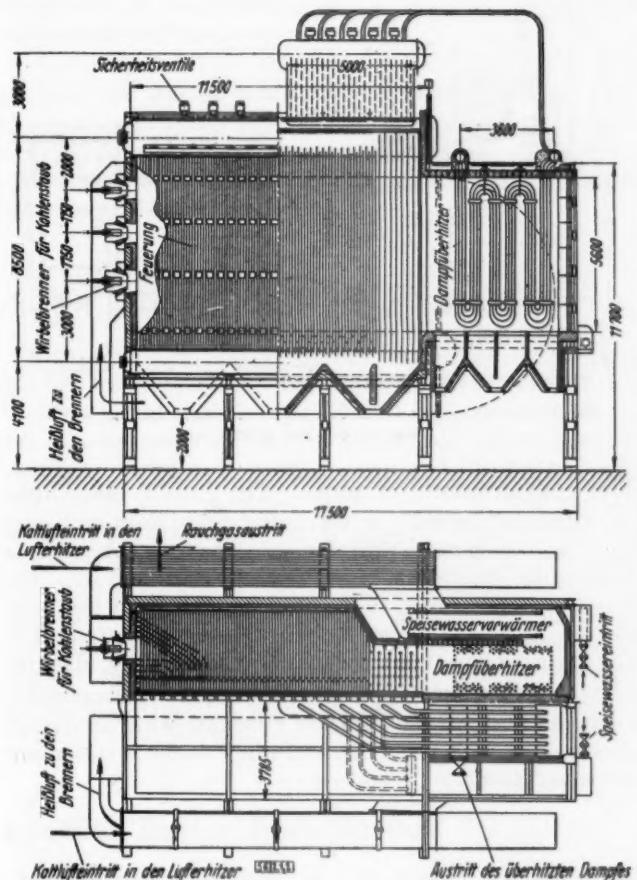
**As reported in the foreign technical press**

## **Boiler Construction in U.S.S.R.**

*Waermewirtschaft* of September 1934 reviews the standardization of boilers and boiler shops in Soviet Russia. A central boiler construction bureau directs the standardization of the boiler types and controls the work done in the various boiler shops. Each shop performs that part of the boiler work most suited to it. The standardization includes units for normal outputs of from 6 to 160 tons of steam per hour, independent

of the type of fuel or firing. Ratings are based on output, pressure and superheat.

Two types are built for each standard rating; for fuels burned on stokers and for pulverized fuel or oil firing. A novel design of the latter type is shown in the illustration here reproduced. The boiler has very little convection surface and is built in flue form through which the gases flow in a horizontal direction. In the back of this flue is a superheater and on either side are arranged air heaters and economizers. The boiler rests on the lower drum and is braced against side sway by a tight structural frame work. The type is designed for pressure of 32 atmospheres (470 lb per sq in.) and an output of 268,000 lb of steam per hr.



### **Sectional elevation and plan of boiler**

safety valves—sicherheitsventile  
superheater—Dampfüberhitzer  
burners for pulverized coal—Wirbelbrenner  
hot air to burners—Heissluft zu den Brennern  
air in—Kaltlufteneintritt in den Luftherzitter  
gas out—Rauchgasaustritt  
burners for pulverized coal—Wirbelbrenner für  
Kolenstaub  
hot air to burners—Heissluft zu den Brenner  
cold air to air heater—Kaltlufteneintritt  
outlet of superheated steam—Austritt des  
überhitzen Dampfes  
boiler feed—Speisewassereintritt  
economizer—Speisewasserwärmer

## **Velox Boiler Comparisons**

*Genie Civil* for August 4 makes certain comparisons between the Velox (pressure combustion) boiler and the ordinary steam boiler. Heat transmission of 92,000 to 110,000 Btu per sq ft of heating surface per hour are given, as compared with 9200 to 11,800 for the ordinary boiler. The relative evaporation, in pounds per square foot of heating surface per hour, are 184 and 14.7 to 18.4, and the Btu per cu ft of furnace per hour are, respectively, 845,000 and 22,500 to 135,000. Striking is the comparison of weights, including auxiliaries, which for the Velox steam generator is given as 1.5 to 2 lb per pound of steam per hour compared with 6 to 10 lb for the ordinary boiler. Test data, reported by the author, shows net efficiencies for the Velox generator of 86.8 per cent at one-quarter load to 92.1 per cent at 12 per cent overload.

## **Underground Coal Carbonization**

The October issue of *Fuel* (London) reviews an experiment carried out in Russia in which coal is carbonized underground at the mine. A pillar of coal was enclosed in a double-walled brick chamber and the cavity rammed with clay. The coal was then ignited and forced draft applied, the gas being taken off through a tube in the walls. Because of leakage in the walls the gas escaped in all directions and the percentage of CO was low. It was found possible to burn only a small part of the pillar. On the second trial the pillar of coal was broken down by blasting and upon re-igniting the coal

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SLAG

Do you have trouble with slag? And is this trouble aggravated by high maintenance charges or failure of soot blower elements in location "A"?

Slag trouble is **real** trouble. From your own experience answer this question: Should a soot cleaner element in location "A" last 2 months—4 months—6 months—? Some elements have failed after as little as two months' service, yet when replaced with **suitable elements**, correctly engineered for the job, the replacement has lasted from two to three years.



It is not all together the materials used. Correct engineering counts. Put your problem up to Bayer engineers.

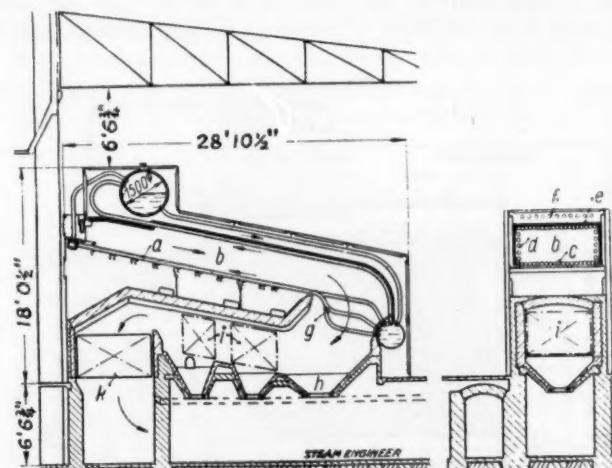
**THE BAYER COMPANY**  
1508 South Grand Blvd., St. Louis, Mo.

the carbonization process increased rapidly. Gas was produced with a calorific value of 989 calories per cubic meter. As a result of these experiments a larger plant is being constructed and the gas will supply steam boilers located at the surface.

## Radiant-Heat Boiler

*The Steam Engineer* (London) for October reviews the Graafen radiant-heat boiler and water-cooled grates—a German design for relatively small units which is said to combine low investment and maintenance costs with high radiant heat transmission and good performance.

Referring to the sketch, the combustion chamber *b* is low,  $2\frac{1}{2}$  to  $3\frac{1}{4}$  ft high, through which the products of combustion flow parallel to the fire bed and the heating surfaces. Air supply to the water-cooled grates is in



Sections through Graafen radiant-heat boiler with water-cooled grate

three compartments, or zones. The grate cooling tubes are connected directly in the boiler circulation and form risers in conjunction with the side and top tubes of the combustion chamber, as shown at *c*, *d* and *e*. The return or downcomer tubes are screened from the combustion chamber. The superheater is indicated at *e*. The grate cooling tubes are bent and spread at *g*, allowing ash to fall into the hopper *h*, and a steaming economizer is located at *k*. Test data are given showing an overall efficiency of 85.3 per cent, including boiler, economizer and superheater.

## Power Plant of the "Queen Mary"

Much attention was given recently by the daily press to the launching of the new giant Cunarder, "Queen Mary." Data on the propelling machinery are given in the October issue of *Engineering and Boiler House Review* (London). The total shaft horsepower will be 200,000, supplied by four 50,000-hp geared turbines each driving a separate propeller. Steam will be furnished by twenty-four Yarrow boilers, arranged in four boiler rooms, and operating at 425 lb pressure and 700 F total steam temperature. A fifth boiler room will con-

tain three double-ended Scotch boilers to supply steam for the various services. The main boilers have forged drums. Air heaters are included. Incidentally, an interesting feature is that over 1000 gallons of "Apexior" compound has been used for coating the boiler surfaces as well as being applied to the interior surfaces of the turbines.

### Claude Making Ice from Ocean Depths

Several years ago, it will be recalled, Georges Claude excited widespread interest by his experiments off the coast of Cuba in developing power by low-head heat derived from the difference in temperature between surface water and that at considerable depth. While his installation actually produced power, the plan was not commercially practical. Undaunted by the results of this experiment, this well-known French scientist has now turned his attention to utilization of the same principle for the production of ice. To this end he purchased a tramp steamer and fitted it out with a complete equipment of evaporators, steam turbines, condensers and ice-making machinery.

On September 4 the vessel sailed for Brazil and is now anchored off Rio de Janeiro. A large tube is being sunk to the ocean depths and the manufacture of ice without the consumption of fuel will be undertaken. This novel installation is described and illustrated in the October 5th issue of *The Engineer* (London).

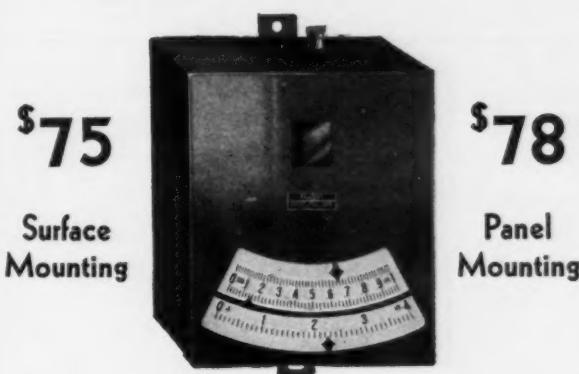
### Frey Flue-Gas Washing System

*Engineering* (London) of September 28 describes a flue-gas washing system known as the "Frey De-dusting Washer," which has lately been developed by Soc. Anon. des Chaudronneries A. F. Smulders, Grâce-Berleur-lez-Liége, Belgium. In this system the mass and surface of the dust particles is increased by first passing them through a fog of water vapor. This renders the particles susceptible to separation by centrifugal action by which they are caused to impinge on a moving film of water. The average of four tests quoted shows an efficiency of 98.8 per cent. The water consumption averaged 0.462 kg per cu meter of gas. The Frey washer shares with other types of wet washers the advantage of decreasing the sulphur content of the flue gas.

### Loeffler Boiler Installation

*Engineering* (London) of October 19 describes the new Trebovice power station in Czechoslovakia in which are installed three Loeffler boilers supplying steam at 1800 lb 930 F to two 21000-kw turbine-generators. Pulverized coal is used and the preheated air to the mills ranges from 750 to 930 F. Steam is reheated to 650 F by steam reheaters between the high- and low-pressure cylinders of the turbines. Three-stage extraction is employed for heating the condensate and steam is extracted at 300 lb to run the auxiliaries. Two low-pressure boilers of conventional type supply makeup to the Loeffler boilers and also to the house turbine when bled steam is not available.

### How to Fire By The DRAFT GAGE



*Ellison 3-Pointer Draft Gage—Dial Type*

This 3-pointer gage is for furnace and uptake drafts and pit pressure of forced draft stokers. For a 3-pointer gage, the boiler should have not less than .25" differential pressure. First adjust the furnace draft and pit pressure, as directed in the October issue, then note the lowest differential pressure between furnace and uptake that will carry the load. Excess air through thinner fuel bed, holes in the fire or too high forced draft pressure is indicated by higher differential readings. Thicker fuel bed or choked fire is indicated by requiring a higher forced draft pressure for the same load and differential reading.

*Third Lesson in December Issue*

**Ellison Draft Gage Company**  
214 West Kinzie Street Chicago

A MODERN type boiler tube of steel or rust-resisting Toncan Iron, made from clean, flat-rolled metal formed cold to a perfect round and then welded by the electric resistance method.

The weld is as strong as the wall. Diameter, concentricity and wall thickness are absolutely uniform. Inside and outside surfaces are smooth and free from scabs, slivers and rolled-in scale. Tubes are full-normalize-annealed, soft, ductile and of uniform grain structure. Every tube is tested at pressures far in excess of code requirements.

Because of these features, Electrunite Boiler Tubes make possible tighter joints with worth while savings in time and labor, and add to the safety and life of equipment. Made in a full range of sizes for fire-tube or water-tube boilers. Write for literature.

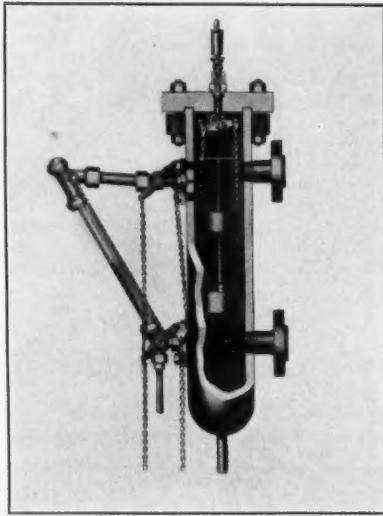
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# NEW EQUIPMENT

of interest to steam plant engineers

## Yarway Water Column Improved

The Yarnall Waring Company, Chestnut Hill, Philadelphia, announce several important improvements in the well-known YARWAY Floatless Hi-Lo Alarm Water Column and Sesure-Inclined Water Gage, here shown. The following standard features have been retained: the use of balanced solid weights, working on displacement principle to operate the



whistle alarm at high and low water levels; attachment of gage valves directly to water column, with chains set well back from gage glass, to allow clear vision of inclined water level in glass and to prevent strain on the glass by chain pull; gage glass inclined from vertical to permit reading water levels from below.

The improvements include a smaller, lighter water column body, a simpler more flexible and more responsive operating mechanism for the Hi-Lo Alarm and an inclined connecting member at top of gage, which drains back the condensate that might otherwise collect at this point and cause erosion and corrosion of the glass.

These water columns and gages are built for working pressures up to 1500 lb per sq in. For pressures up to 250 lb, the water column is made of cast iron; for higher pressures, it is wrought steel. Tubular gage glasses are used for pressures up to 400 lb for higher pressures, flat glass inserts are furnished. A special feature of the heavy duty flat glass insert is an offset condensate groove which carries condensate down alongside the glass, thereby eliminating the corrosive and erosive action of this moisture.

## Close-Coupled, Turbine-Gear Equipment

A new line of close-coupled, turbine-gear sets, each set consisting of a steam turbine and speed-reducing gear, has been announced by the General Electric Company. These are designed to drive cen-

trifugal pumps, fans, and other relatively low-speed apparatus by means of the speed reducing gear, the turbine operating at a relatively high and efficient speed. The sets are particularly applicable where exhaust steam can be used for heating purposes.

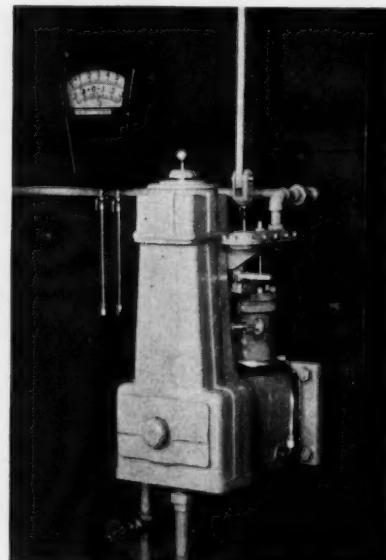
The housings of the turbine and gear are bolted together to form a single structure supported on the base of the turbine. This arrangement provides a compact unit with a minimum of bearings and assures a correct alignment of turbine and gear.

The turbine can be arranged to operate at steam pressures up to 400 lb, temperatures up to 750 F, and back pressures up to 40 lb gage. The speed of the low speed shaft may be within the range of 180 to 3000 rpm. The capacity of this new line of turbine-gear sets ranges from 10 to 150 hp.

## Automatic Regulator

A new regulator of the fluid-operated type, for application to combustion control, pressure temperature, volume or speed regulation, and designed for sensitivity yet freedom from hunting, has recently been announced by the General Regulator Company, 50 Church Street, New York.

As will be seen from the illustration the working parts are completely enclosed. Inside the casing is a regulating cylinder, a stabilizing valve and a relay valve, mounted one above the other and moving



in the same axis. An amplifying valve, balance lever and stabilizing jets are located above the regulating cylinder and a return motion mechanism is located in the regulator base just below the relay valve.

The fluid is discharged through a jet on to an arm to which the amplifying valve is responsive and thus provides the required stabilizing force. A very small

diaphragm is employed which tends to reduce lag due to inertia and thus provide quick response.

## Bronze Gate Valve

A new heavy standard bronze gate valve for 150 lb steam pressure and 250 lb water pressure has been announced by the Kennedy Valve Manufacturing Company, Elmira, N. Y. This has a large bonnet hex located close to the body to provide rigidity and make for easier removal of the bonnet and stem assembly. The stem is of especially tough bronze and has a large number of contact threads. A deep stuffing box is provided with high-graphite moulded packing rings, bronze gland and heavy packing nut. The valves are built in sizes up to 3 in.



## Welding Electrode

A new heavily coated arc-welding electrode, designated as G-E Type W-23, for the production of high-speed, high-quality welds for such work as pressure vessels, pipe and equipment, in the flat position, has been announced by the General Electric Company. These electrodes are suitable for either manual or automatic arc welding and will produce equally good results on either alternating or direct current. With the latter, reverse-polarity is used.

The element of economy in the production of high-quality welds is provided by the ability of this electrode to operate at higher speeds, in larger diameters ( $\frac{1}{4}$ ,  $\frac{5}{16}$  and  $\frac{3}{8}$  in.), and at higher current values than those commonly in use. Another characteristic is the fact that such welds fuse uniformly with the side walls of the joint—thus saving the time and labor ordinarily spent in chipping out slag from pockets at the line of fusion. On most work, the production rate with Type W-23 is greater than with other heavily coated electrodes and two to three times the rate with bare or lightly fluxed electrodes.

Typical physical characteristic values for W-23 welds are tabulated below:

AFTER STRESS RELIEVING AT 1200 F		
	Results of 5 Tests	
	Average	Range
Ultimate tensile strength—lb per sq in.	65,840	65,400-66,700
Yield point—lb per sq in.	54,460	50,800-56,600
Per cent elongation in 2 in.	31.6	29.5-34.5

WITHOUT STRESS RELIEVING		
	Results of 9 Tests	
	Average	Range
Ultimate tensile strength—lb per sq in.	69,550	67,400-71,300
Yield point—lb per sq in.	56,355	50,500-60,300
Per cent elongation in 2 in.	27.2	24.5-30
Impact resistance—30 to 40 ft lb (Charpy)		
Free-bend ductility values range from 40 to 60 per cent.		

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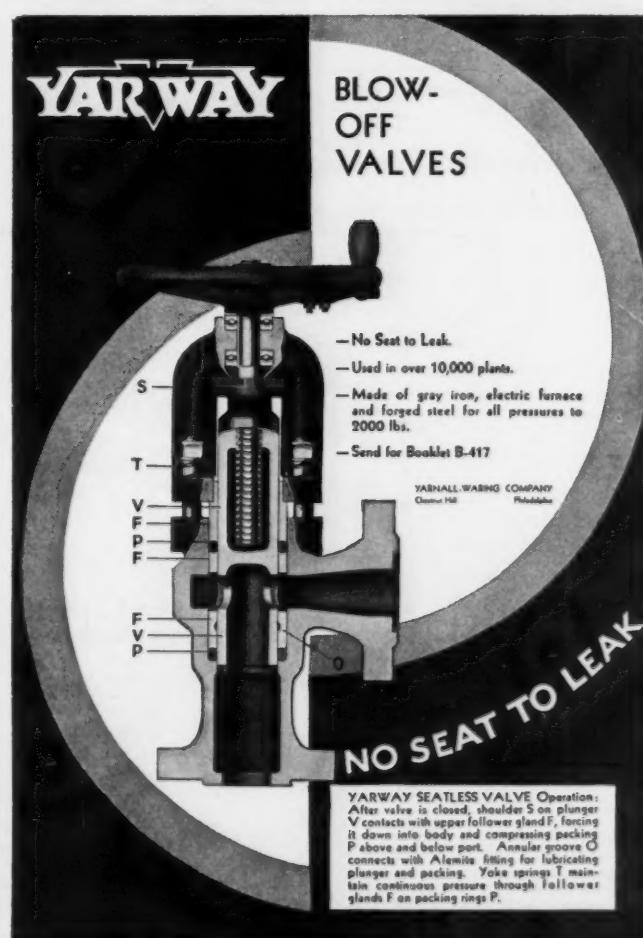
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# EQUIPMENT SALES

## Boiler, Stoker, Pulverized Fuel

As reported by equipment manufacturers of the Department of Commerce, Bureau of the Census

### Boiler Sales

Orders for 63 water-tube and h.r.t. boilers were placed in August

	Number	Square Feet
September, 1934.....	63	171,554
September, 1933.....	102	296,234
January to September (inclusive, 1934).....	683	2,007,042
Same period, 1933.....	737	2,262,154

#### NEW ORDERS, BY KIND, PLACED IN SEPTEMBER, 1933-1934

Kind Stationary:	September, 1933		September, 1934	
	Number	Square Feet	Number	Square Feet
Water tube.....	53	233,473	33	134,867
Horizontal return tubular.....	49	62,761	30	36,687
	102	296,234	63	171,554

### Mechanical Stoker Sales

Orders for 280 stokers, Class, 4\* totaling 41,527 hp were placed in September by 60 manufacturers

	Installed under							
	Fire-tube Boilers				Water-tube Boilers			
	No.	Horsepower	No.	Horsepower	No.	Horsepower	No.	Horsepower
September, 1934.....	240	27,767	40	13,760				
September, 1933.....	175	21,667	28	10,518				
January to September (inclusive, 1934).....	1,030	133,163	374	146,322				
Same period, 1933.....	833	106,250	337	123,175				

\* Capacity over 300 lb of coal per hr.

### Pulverized Fuel Equipment Sales

Orders for 6 pulverizers with a total capacity of 18,430 lb per hr were placed in September

	STORAGE SYSTEM									
	Pulverizers				Water-tube Boilers					
	Total number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb coal per hour for contract	Number	Total sq ft steam-generating surface	Total lb steam per hour equivalent			
September, 1934.....	..	..	..	..	..	..	..	..	..	..
September, 1933.....	..	..	..	..	..	..	..	..	..	..
January to September (inclusive, 1934).....	2	1	1	46,000	4	109,432	1,445,000			
Same period, 1933.....	6	4	2	220,000	4	109,432	1,445,000			

### DIRECT FIRED OR UNIT SYSTEM

	Pulverizers				Water-tube Boilers				Fire-tube Boilers	
	Pulverizers		Water-tube Boilers		Fire-tube Boilers					
	September, 1934.....	3	2	1	15,400	3	16,740	143,500		
September, 1933.....	23	12	11	123,100	18	114,828	1,141,100			
January to September (inclusive, 1934).....	68	50	18	453,180	53	365,403	3,897,200			
Same period, 1933.....	77	54	23	434,400	62	409,398	3,914,060			

### University of Illinois Studying Removal of Sulphur from Flue Gases\*

The Chemical Engineering Division of the Engineering Experiment Station at the University of Illinois is studying methods for the removal of sulphur dioxide from boiler furnace gases.

A comprehensive study has been made of a catalytic oxidation method in which the sulphur dioxide and oxygen are caused to react after absorption to produce dilute sulphuric acid. For pure gases this method has the advantage of requiring only approximately one per cent of the water required by simple absorption. A product containing as much as forty per cent acid may also be produced. Because of the slow absorption of oxygen, however, the time of contact is not reduced in washers suitable for handling large quantities of gases with low draft losses. For flue gases from the combustion of coal, impurities render the catalysts inactive and not more than four per cent acid may be produced.

A second method involving the use of solutions of certain ammonium salts as selective absorbents is now being studied. With absorption taking place at 95 F and regeneration at 160 F these absorbents have a capacity as high as 7 lb of sulphur dioxide per 100 lb of solution circulated. The sulphur dioxide in the effluent gas can be reduced to 0.03 per cent. The method has the advantage of requiring only a small quantity of a cheap solvent, of giving rapid absorption and of producing pure sulphur dioxide as a by-product.

\* Statement contained in Prime Movers Report on "Steam Generation," August 1934.

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